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TELEPHONE CABLES

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TELEPHONE CABLES

A HANDBOOK OF

THE DESIGN, CONSTRUCTION AND MAINTENANCE

OF THE

TELEPHONE CABLE PLANT

By J. C. SLIPPY

Published by
J. C. Slippy—Pittsburgh, Pa.
1913

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PREFACE.

During an experience in the telephone field as engineer for various operating companies, the need has often been felt for a handbook which would contain, in handy, ready-reference form, the principal data which is required almost daily by those who have to do with modern cable plant layout, installation and maintenance. Following out this idea, the matter in the succeeding pages has been compiled.

The title "Telephone Cables" is perhaps a misnomer, as there are many features of telephone cable work and appliances of merit, which are not described. Among those which might be noted are detail methods of using cable in interior block distribution, switchboard and building cables, the installation of submarine cables, and various appurtenances which in some sections of the country enter into the construction of the cable plant. While these matters are important, they are not of daily concern to the majority of telephone cable men, and when occasion for their use does arise, can be found described in the standard works of Arthur Vaughan Abbott, Kempster B. Miller, and other authorities. Furthermore, the aim has been not to make a big book, but an every-day, useful one.

It should be borne in mind that no hard and fast rules can be laid down for telephone cable work on account of the varying conditions and costs in different sections of the country, and that the value of any given economy is directly dependent on local conditions. For this reason the recommendations made herein, while representative of the best modern practice, should be followed with discretion.

It is desired here to pay a tribute to the memory of Myron C. Clark, whose encouragement had much to do with the preparation of the present volume.

J. C. S.

May 1, 1913.

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TELEPHONE CABLES.

CHAPTER I.
CABLE SPECIFICATIONS.

General:—From the earliest stage of the telephone industry, many wires had to be handled in the back of switchboards. In order to systematize them and to economize space, they were formed into cables; hence the invention of the switchboard cable. Then came the difficulty of carrying great numbers of wires through the streets to reach subscribers' residences, so various forms of subscriber cables were designed.

The term cable as here used will be limited to cables employed in outside telephone construction work at the present time. Under this classification are five principal kinds, each one of which has a special use. These are known as lead covered dry core, lead covered wool insulated, lead covered rubber, okonite and submarine. In taking up the discussion of the several kinds, a short description of the use, electrical and mechanical requirements of each cable and a complete specification for lead covered dry core cable with No. 22 B. & S. gauge conductors will be given. With this information it is a comparatively simple matter to draft specifications for any kind of cable which will operate to prevent the furnishing of cable not up to standard.

Lead Covered Dry Core Cable:—Lead covered dry core cable has been adopted for general use in telephone work because of its low electrostatic capacity, durability, high insulation resistance and cheapness as compared with rubber covered or other varieties of cable. It is made in sizes ranging from 10 to 600 pairs, with conductors from No. 22 to No. 10 gauge, and having different electrostatic capacities, according to the service requirements.

In making lead covered dry core cable each conducto*is insulated with* one or two wrappings of the highest gra*paper tape.* After receiving this covering the indivi

conductors are twisted into pairs, the length of twist depending upon the gauge of the cable, and these pairs formed into a core arranged in reversed layers. This core is then given a wrapping of heavy paper, baked thoroughly dry, and covered with a lead sheath. The insulation of dry core cable remains high until the lead sheath is injured to such an extent that it will admit moisture, which gives so much trouble as to necessitate immediate repair. Fig. 1 represents a high type of dry core cable, from a photograph loaned by the Standard Underground Cable Company.

Fig. 1. Lead Covered Dry Core Cable.

It will be noted that the specifications given for lead covered dry core cable provide for a color scheme in the insulation of the conductors of cables of two hundred pairs and over. This is considered an economy on account of the saving of splicer's time in testing out the cable, and because there is very much less damage done to the insulation of the wires in picking out pairs in a tap splice or in case of trouble. The additional cost of this feature is about one-eighth of a cent per foot for each group of pairs so distinctively colored, making the cost of a four hundred foot length of 400 pair cable under this specification $2.00 more than for the ordinary cable.

The methods of testing cables for electrostatic capacity are known as the "grounded" test and the "mutual" test. In the grounded test the capacity of each wire is measured

against all remaining wires grounded to the sheath. The mutual test consists of measuring the capacity between one wire of a pair and its mate, the remaining conductors and the sheath being grounded. The mutual test is now standard practice with the majority of telephone companies, as the influence of capacity on voice currents is dependent upon the amount of mutual or shunt capacity.

The remaining requirements of the specifications are so familiar to cable men as to need no comment.

Gauges of Cables:—The gauge of wire to use in any portion of the cable plant is dependent upon the grade of transmission which it is desired to provide for the district, the average length of subscriber and trunk lines, and the amount of trunking between offices. Where no particular data affecting the above is at hand, the following limits may be observed.

No. 22 B. & S. gauge cable with an average mutual electrostatic capacity of .069 microfarads per mile is used for all subscriber loops (distance between the terminal on a cable and the central office) when the length of the cable will not make the resistance of the loop over 400 ohms for single office districts, and 300 ohms for multi-office districts. The length of loop for which this cable is used should not exceed 1¾ miles.

No. 19 B. & S. gauge cable with an average mutual electrostatic capacity of .080 microfarads per mile is used for subscriber loops having a length not exceeding 3¼ miles. It is evident that in cases in which the distance of the terminal from the office is more than 1¾ miles and less than 3¼ miles, the most economical cable would be a combination of cables having No. 22 and No. 19 gauge conductors. For these cases, the following combinations are recommended, the 22 gauge cable being placed at the central office end of the line.

TABLE I.

LIMITING LENGTHS OF SUBSCRIBER CABLES.

Loops having length of 0 to 1¾ miles, use 22 gauge cable
Loops having length of 1¾ to 2 miles, use
1½ miles of 22 gauge cable
½ mile of 19 gauge cable
Loops having length of 2 to 2¼ miles, use
1 mile of 22 gauge cable
1¼ mile of 19 gauge cable
Loops having length of 2¼ to 2½ miles, use
½ mile of 22 gauge cable
2 miles of 19 gauge cable
Loops having length of 2½ to 2¾ miles, use
¼ mile of 22 gauge cable
2½ miles of 19 gauge cable
Loop having length of 2¾ to 3¼ miles, use 19 gauge cable

No. 19 B. & S. gauge cable with an average mutual electrostatic capacity of .054 microfarads per mile is used for toll or trunk lines of considerable length that are used in connection with toll lines. Cables having conductors of larger size are used for toll lines of greater length, being designed for use in connection with loading coils and phantom circuits.

Specifications for Lead Covered Dry Core Cable With No. 22 B. & S. Gauge Conductors:

These specifications apply to cables of four hundred (400) pairs and less of No. 22 Brown and Sharpe gauge conductors.

Agreement:—The materials used in the manufacture of the cable must be of the quality herein specified and the electrical properties and the methods of manufacture must be those called for herein. The quality of the materials used and the electrical properties of the cable shall be determined by the manufacturer before the cable is delivered.

The telephone company is to have the right to make *such tests of the quality of* the materials used, and of the *lectrical properties of the finished* cable, as it may desire.

The inspector of the telephone company is to have the power to reject the cable should the qualities of the materials used or the electrical properties of the cable fall below the requirements herein specified.

The manufacturer shall guarantee that for one year from the time cables are placed, spliced and connected to terminals, the electrostatic capacity and the resistance of the conductors shall not have increased, nor the insulation resistance have decreased, beyond the limits herein specified, due to defective material or manufacture. The manufacturer, shall, however, not be responsible for the failure of cables brought about by injuries to the sheath or conductors due to causes beyond his control.

Conductors:—Each conductor shall be of soft copper and of such conductivity as will insure, at all seasons of the year, a conductor resistance for each length of cable, of not more than ninety-five (95) ohms for each mile of cable.

Insulation:—Each conductor shall be insulated with paper tape laid spirally around the wire; each turn of the paper tape shall cover at least fifty (50) per cent. of the turn preceding it. The thickness of the paper shall be at least twenty-five ten-thousandths (.0025) of an inch.

Core:—The insulated conductors, colored as specified, shall be twisted in pairs, the length of twist not to exceed three (3) inches, and formed into a cylindrical core arranged in reversed layers. In the outside layer of the core shall be carried a test pair which shall be colored distinctively in such a manner as to be readily distinguishable from any other pair in the cable. The core shall be covered with two wrappings of paper, the paper to be not less than four thousandths (.004) of an inch in thickness, and to be so laid on that all portions of the core are covered with at least two thickness of paper.

Colors of Pairs:—Cables of two hundred (200) pairs or more shall have the insulation of the conductors colored as follows:

Pairs 1 to 100, red and white.
Pairs 101 to 200, blue and white.
Pairs 201 to 300, green and white.
Pairs 301 to 400, red and green.

The test pair shall be colored red and blue.

The different colored pairs shall take the following positions in the core: The center of the core shall consist of the blue and white pairs (101-200); the next layers of the red and white pairs (1-100); the next layers of the green and white pairs (201-300); and the next layers of the red and green pairs (301-400).

Filling of Ends:—The ends of each and every length of cable shall be filled with an approved insulating compound, which shall seal the cable for a distance of at least two (2) feet.

Sheath:—The core shall be enclosed in a sheath of uniform thickness composed of lead and tin, the amount of tin to be not less than three (3) per cent. The sheath shall be formed around the core, and shall be free from holes or other defects. The thickness of the sheath shall be in accordance with Table II.

TABLE II.

THICKNESS OF SHEATH, 22 GAUGE CABLE.

Number of Pairs.	Thickness of Sheath.
1 to 99 pairs inclusive,	Not less than 1/12" (.083)
100 to 199 pairs inclusive,	Not less than 3/32" (.094)
200 pairs and over,	Not less than 1/8" (.125)

The outside diameter of the cable manufactured under these specifications shall not be more than two and five-eighths (2⅝) inches.

Electrostatic Capacity:—In every length of cable, the average mutual electrostatic capacity, at any season of the year, measured between one wire of a pair and its mate (the remainder of the conductors and the sheath being grounded) shall not exceed sixty-nine thousandths (.069) of a microfarad per mile of cable. The mutual electrostatic capacity of any pair of the cable so measured shall not exceed seventy eight-thousandths (.078) of a microfarad per *mile of cable.*

These figures apply only to the paper cable, and proper *allowance must be made for* the rubber covered wire used *terminals.*

Insulation Resistance:—Each wire shall have for each length of cable an insulation resistance of not less than five hundred (500) megohms per mile of cable, each wire being measured against all the rest and the sheath with an electromotive force of from 500 to 550 volts.

Marking of Reels:—Each reel of cable shall be plainly marked with the reel number, the name of the manufacturer of the cable, and the location of the factory to which the reel is to be returned; also the cable number; the number of feet in the reel of cable; the number of pairs in the cable; the gauge of wire of the cable conductors and their electrostatic capacity. At least eighteen (18) inches of the inside of the cable shall be brought out through the side of the reel so as to be accessible for testing. This end shall be securely boxed to protect it from mechanical injury. The outside end of the cable shall be securely fastened so that it will not become loose during transportation.

Lead Covered Dry Core Cable With No. 19 B. & S. Gauge Conductors, High Capacity Cable.

These specifications apply to cables of 300 pairs and less of No. 19 Brown and Sharpe gauge conductors with the high capacity requirement.

Conductors:—Each conductor shall be of soft copper and of such conductivity as will insure, at all seasons of the year, a conductor resistance of not more than forty-seven (47) ohms for each mile of cable.

TABLE III.

THICKNESS OF SHEATH, NO. 19 GAUGE CABLE.

Number of Pairs.	Thickness of Sheath.
1 to 49 pairs inclusive,	Not less than 1/12″ (.083)
50 to 99 pairs inclusive,	Not less than 3/32″ (.094)
100 pairs and over,	Not less than 1/8″ (.125)

The outside diameter of any cable manufactured under *these specifications* shall not be more than two and five *eighths (2⅝)* inches.

Electrostatic Capacity:—In every length of cable, the average mutual electrostatic capacity, at any season of the year, between one wire of a pair and its mate (the remainder of the conductors and the sheath being grounded), shall not exceed eighty thousandths (.080) of a microfarad per mile of cable. The mutual electrostatic capacity of any pair so measured shall not exceed eighty-seven thousandths (.087) of a microfarad per mile of cable. These figures apply only to the paper cable, and proper allowance must be made for the rubber covered wires used at terminals.

Requirements for **Agreement, Insulation, Core, Filling of Ends, Insulation Resistance** and **Marking of Reels** shall be the same as for cable with No. 22 B. & S. gauge conductors.

Lead Covered Dry Core Cable with No. 19 B. & S. Gauge Conductors, Low Capacity Cable.

These specifications apply to cables of 200 pairs and less of No. 19 Brown and Sharpe gauge conductors with the low capacity requirement.

Electrostatic Capacity:—In every length of cable, the average mutual electrostatic capacity, at any season of the year, measured between one wire of a pair and its mate (the remainder of the conductors and the sheath being grounded) shall not exceed fifty-four thousandths (.054) of a microfarad per mile of cable. The mutual electrostatic capacity of any pair of the cable so measured shall not exceed sixty (.060) thousandths of a microfarad per mile of cable.

Core, Length of Twist:—The insulated conductors, colored as specified, shall be twisted in pairs, the length of twist not to exceed six (6) inches, and formed into a cylindrical core arranged in reversed layers.

Conductor Resistance and **Thickness of Sheath** shall be the same as for No. 19 B. & S. gauge high capacity cable; and requirements for **Insulation, Filling of Ends, Insulation** ***Resistance, Agreement*** *and* **Marking of Reels** as for No. 22 *B. & S. gauge cable.*

Lead Covered Dry Core Cable with No. 16 B. & S. Gauge Conductors.

These specifications apply to cables of 100 pairs and less of No. 16 Brown and Sharpe gauge conductors.

Conductors:—Each conductor shall be of soft copper and of such conductivity as will insure, at all seasons of the year, a conductor resistance for each length of cable, of not more than twenty-three (23) ohms for each mile of cable.

Electrostatic Capacity:—In every length of cable, the average mutual electrostatic capacity at a temperature of 68 degrees Fahrenheit, between one wire of a pair and its mate (the remainder of the conductors and the sheath being grounded) shall not exceed seventy-two thousandths (.072) of a microfarad per mile of cable. The mutual electrostatic capacity of any pair of the cable so measured shall not exceed eighty thousandths (.080) of a microfarad per mile of cable.

Requirements for **Agreement, Insulation, Core, Filling of Ends, Sheath, Insulation Resistance** and **Marking of Reels** shall be the same as for low capacity cables with No. 19 B. & S. gauge conductors.

Lead Covered Wool Insulated Cable:—Lead covered wool insulated cable is used for terminating the exchange ends of lead covered dry core cables on the fuse rack. It should be of sufficient length to form a good seal for the dry core cable, this dimension being not less than 8 feet and for economy's sake not more than 50 feet.

Each conductor is of tinned copper, usually of No. 22 B. & S. gauge, insulated with two layers of wool wrapped in reversed directions. While wool insulation is not so good electrically as rubber, it is much stronger mechanically. The insulation resistance is 100 megohms or over per mile of cable for each conductor measured against all the rest and the sheath grounded. The average mutual electrostatic capacity for each conductor is .092 microfarads per mile, measured against its mate, all the other wires and the sheath being grounded. The lead sheath should not be less than 1/12 of an inch in thickness for cable of 100 pairs or less and for larger sizes not less than 3/32 of an inch. This cable is made in sizes from 25 to 200 pairs.

Lead Covered Rubber Cable:—This cable was devised for the purpose of taking taps out of lead covered dry core cable, and obviated the making of potheads on the connecting cable. So much trouble has been experienced by the softening of the rubber at the splice to the main cable and from the corrosion of the untinned dry core cable conductors by sulphur in the rubber that many cable terminals have been placed on the market which provide some means of using dry core cable as a connecting cable. See Chapter III. Cable Terminals.

Lead covered rubber cable is made up with either No. 19, No. 20, or No. 22 B. & S. gauge, tinned, soft copper conductors insulated with rubber to a thickness of about 3/32 of an inch. The conductors are twisted in pairs, the length of twist being about 3 inches, and made into a core, arranged in reversed layers, the whole being covered with a lead sheath ⅛ of an inch thick.

Fig. 2. Lead Covered Rubber Cable.

The conductor resistance is the same as that for lead covered dry core cable with the same gauge conductors. The mutual electrostatic capacity is high, averaging .17 microfarads per mile for cable with No. 19 B. & S. gauge conductors. The insulation resistance is high when new (1000) megohms per mile of cable), but gradually decreases. Rubber cable is made in 10, 15, 25 and 50 pairs. Fig. 2 illustrates a section of rubber cable, from a photograph loaned by the Standard Underground Cable Company.

***Okonite* Cable:**—A class of cable which has a limited *field of usefulness, is known* as okonite. It is used for *mergency work, and in* some cases is substituted for lead *vered dry core cable* between an office pole and the central

office, to obviate the high cost of potheads that would be required with the use of lead covered dry core cable. This cable is sometimes made up with large gauge conductors and used to bring in toll lines from the office pole to the central office.

Okonite cable is usually made up with conductors of No. 19 B. & S. gauge soft drawn copper wire, and the core is formed up similar to lead covered rubber cable, except that the okonite cable is served with a wrapping of jute, and two layers of waterproof tape applied in reversed directions, replaces the lead sheath. The conductor resistance, insulation resistance, and electrostatic capacity are practically the same as that of lead covered rubber cable.

Sometimes it is desirable to provide a cable of this class with a very tough, abrasion resisting sheath. For such cases the protecting covering may be a braid with a circular loom weave, saturated with waterproof compound and covered with small mica flakes.

Submarine Cables:—The various kinds of submarine cables in use today are as follows:

Fig. 3. Submarine Cable.

(a) A paper insulated lead covered cable with core saturated with a bituminous, waterproof compound. This cable is very well protected, as in case of injury to the covering the damage is limited to the lead sheath.

(b) Standard dry core cable with the lead sheath composed of two layers, the first being ⅛ of an inch thick, and the second 5/32 of an inch.

(c) Standard lead covered dry core cable wrapped with several layers of jute or similar material, and protected with an armor of No. 4 B. W. G. galvanized iron wire. Fig. 3 illustrates a section of this class of cable, which is from a photograph loaned by the Standard Underground Cable Company. The general use of this style of cable is recommended for submarine work.

CHAPTER II.
CABLE PLANS.

It is obvious that the economics to be affected in cable construction are primarily matters of systematic design, and because of the relatively large expenditure involved in this portion of the plant it becomes evident that the preparation of a careful plan to secure the maximum economy, both present and future, is warranted.

Definition:—The most simple method of defining a cable plan is to say that it is a map which shows the location and sizes of all cables necessary for the most economical provision of telephone service throughout a community for a number of years.

Scope of Cable Plan:—The cable plan should consist of:

First, a map showing the present conduit system with location of manholes, number of ducts between manholes, location of laterals to poles and buildings, engineered distances between manholes; and the conduit extensions required to cover the growth expected in a five year and ultimate period, the location and number of ducts being indicated. A specimen conduit plan is shown in Fig. 4, the present construction being indicated by short dotted lines, the construction required for a five year period by short dashes with alternate dashes omitted, and that for the ultimate period by long dashes.

Second, a map showing the present underground and aerial cable system, and the cable extensions required to cover the growth expected in a five year period, the location, sizes and gauges of all cable being indicated. Fig. 5 illustrates a specimen cable plan, the present plant being indicated by the full lines, and the construction required for the five year period by broken lines. It is not considered advisable to place more cable at the present time than is indicated by the five years' growth.

Basis of Plan:—Before attempting to make the cable plan, some idea must be had of the number of telephones expected in the exchange area at future periods of time. This is accomplished by making a "development" study

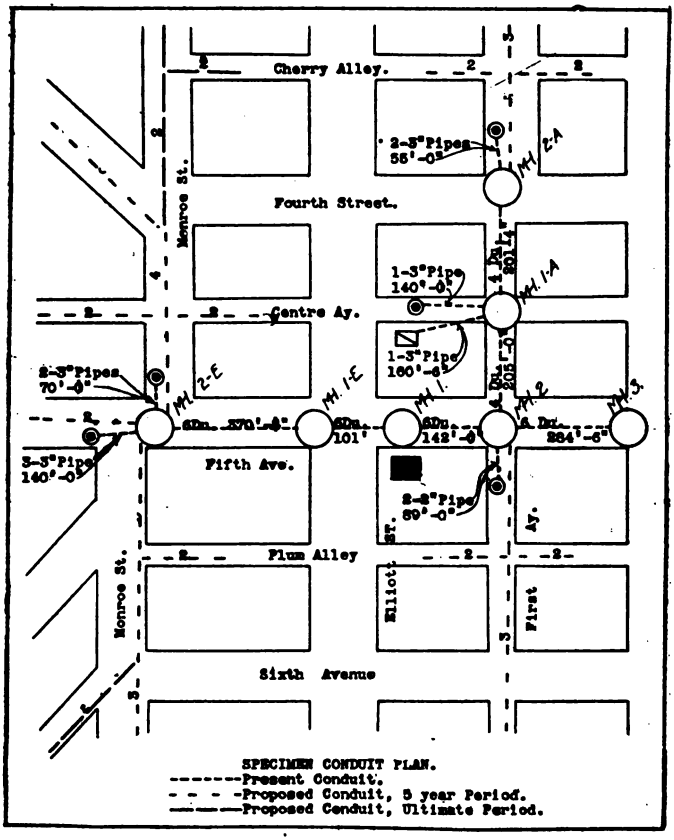

Cherry Alley.
Monroe St.
Fourth Street.
Centre Ay.
Fifth Ave.
Plum Alley
Sixth Avenue
Elliott
First
Ay.
2-3"Pipes 55'-0"
1-3"Pipe 140'-0"
1-3"Pipe 160'-6"
2-3"Pipes 70'-0"
3-3"Pipes 140'-0"
2-3"Pipes 89'-0"
MH. 2-A
MH. 1-A
MH. 2-E
MH. 1-E
MH. 1.
MH. 2.
MH. 3.
6Dn. 170'-0"
6Dn. 101'
6Dn. 142'-0"
6 Dn. 284'-6"
4 Dn. 205'-0"
4 Dn. 201'-6"
SPECIMEN CONDUIT PLAN.
Present Conduit.
Proposed Conduit, 5 year Period.
Proposed Conduit, Ultimate Period.

Fig. 4.

each square in the exchange district, and from the character of the property with which it is expected to provide telephone service in the future, determining the probable number of lines expected in each square at the end of twenty years (termed the ultimate period), and the probability of growth at the end of five years. The five year estimate serves as an indication of the probable growth of the exchange between the present and ultimate time, and enables the distributing cable and the smaller portions of the main cable plant to be planned in the most economical manner.

Skeleton Feed:—After making the development study, a map is prepared showing how each of the subscribers' lines is to be routed from the central office in order to give each a service loop of minimum length. In preparing this map the five year and ultimate distribution of subscribers' lines should be copied on a blank map, the most convenient manner of showing the two estimates for each square being to place a fraction in the upper right hand corner of the square, the numerator representing the ultimate and the denominator the five years' estimate. The number of farmer and toll lines expected in five years should be shown at the points where they will enter the exchange district. From the skeleton feed are determined the streets or alleys on which cable should be placed; aerial cable leads should follow the routes indicated by it so that when it becomes necessary to change from aerial to underground construction, this can readily be done. The existing construction should be rearranged and extended on the map in order to reach all the prospective subscribers, and the skeleton feed be checked over by an inspection of the different routes to determine their possibility and desirability. After the field inspection has been completed, a permanent record of the approved layout should be made, showing the size of cable on each lead, as described in the following paragraphs.

Alley Distribution:—Often when the theoretically best location for a cable lead is indicated on a street, it will be found that it can be placed in an adjacent alley without undue increase in cost. As poles placed in alleys for distribution purposes can also be used for supporting cable

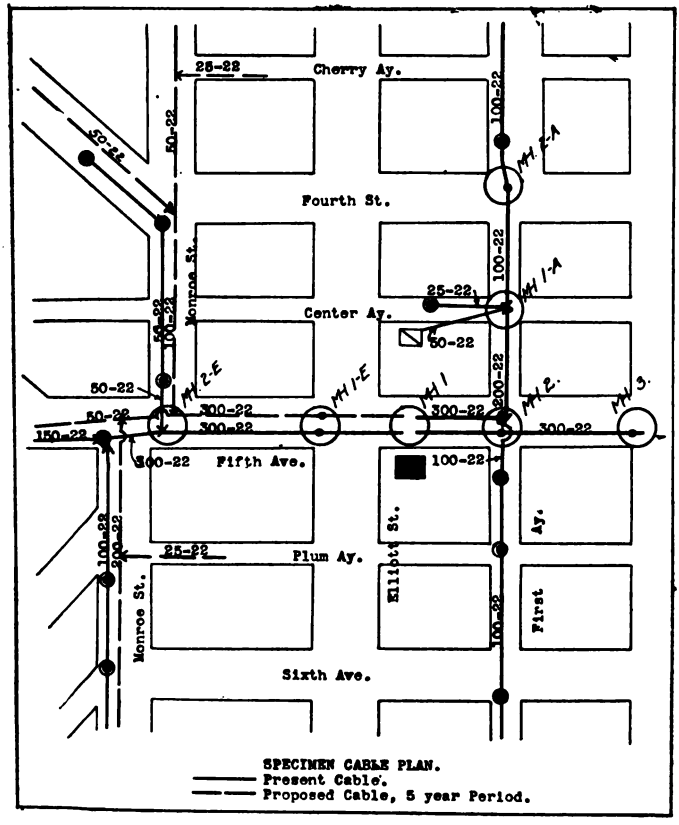

25-22
Cherry Ay.
100-22
MH 2-A
50-22
50-22
Fourth St.
Monroe St.
100-22
100-22
MH 1-A
25-22
Center Ay.
50-22
50-22
MH 2-E
MH 1-E
MH 1
MH 2.
MH 3.
50-22
50-22
300-22
300-22
300-22
300-22
150-22
300-22
Fifth Ave.
100-22
Elliott St.
Ay.
100-22
200-22
25-22
Plum Ay.
Monroe St.
First
100-22
Sixth Ave.
SPECIMEN CABLE PLAN.
Present Cable.
Proposed Cable, 5 year Period.

Fig. 5.

it is considered advantageous to use this form of distribution wherever possible. Where alleys do not exist, distribution from short poles set on private rights of way within the square may be economical.

Underground Construction:—In the case of existing plant with well maintained pole lines, these should never be abandoned for underground construction as long as they are capable of continued efficient service. The investment in plant account will be reduced by postponing underground construction as long as possible consistent with such factors as municipal requirements, the advantages to the telephone company of securing the occupancy of the streets, freedom from interference and hazard from foreign circuits, the possibility of expensive paving in the future, etc. A comparison of the annual costs on aerial and underground plant shows that, in general, it is economical to plan for an aerial capacity of 400 pairs of cable with No. 22 B. & S. gauge wires before placing the lead underground. Where conduit is installed, the capacity of the duct runs placed should be sufficient to care for the present requirements, plus about forty per cent.

Joint Construction:—Where it is possible to secure a satisfactory agreement with an electric light company and have the construction work done under standard specifications for the joint use of poles, telephone distribution will in this way often be obtained at a minimum cost.

Design of Main Cable Feeders:—On account of the heavy proportionate investment in main cable plant, the number of cable pairs entering the central office should be designed to care for only the immediate growth. This number will usually approximate to three-fourths of the estimated five year lines.

The size of main cable feeders must be designed with reference to the following:

(a) Present load.

(b) The existence of a rate schedule which will permit immediate possibilities to be converted into subscribers. Should changes in the rate schedule be expected, the revised rates should be predicted and cable facilities be estimated according to these rates.

(c) Whether the business in the territory considered is subject to competition. The most simple method of making allowance for the competing company is to estimate the total number of lines which such company will have exclusively in five years, and deduct this number from the five year distribution.

(d) The efficiency of the contract department. This is taken as being sufficient to secure all subscribers estimated in the development plan.

(e) As the most successful campaign for the securing of subscribers can be made after the installation of cable facilities, in making the cable plan consideration should be taken of the time required to construct the plant.

Size of Cable to Install:—In studying the annual costs on different sizes of cables with No. 22 B. & S. gauge conductors the following general rules for the size of cable to place on a lead have been deduced. The number of lines on each route of the skeleton feeder map should be totalled for the 5-year and 20-year periods and a curve drawn showing the growth of each lead, the proper size of cable to install being determined from the schedules:

Aerial Cable, Applied to the First Cable Placed on a Lead.

Use 15 pair cable only where it will care for the ultimate.

Use 25 pair cable where the number of lines will not exceed 20 in eight years.

Use 50 pair cable where the number of lines will not exceed 40 in six years.

Use 100 pair cable where the number of lines will not exceed 90 in three years.

Use 200 pair cable where the number of lines will not exceed 180 in five years.

Use 300 pair cable where the number of lines will not exceed 270 in six years.

Underground Cable, With Unlimited Duct Space.

Use 100 pair cable where the number of lines will not *exceed 90 in two and* one-half years.

Use 200 pair cable where the number of lines will not *xceed 180 in six years.*

Use 300 pair cable where the number of lines will not exceed 270 in seven years.

Use 400 pair cable where the number of lines will not exceed 360 in seven years.

Underground Cable, Available Conduit Space Limited to One Duct.

Use 100 pair cable where the number of lines will not exceed 90 in nineteen years.

Use 200 pair cable where the number of lines will not exceed 180 in twelve years.

Use 300 pair cable where the number of lines will not exceed 270 in thirteen years.

The above figures are based upon an efficiency of total pairs in use averaging 80 per cent. for branch cables and 90 per cent. for main cables. It should be noted that where the available conduit space is limited, small sizes of cable should not be used unless they will care for the ultimate number of lines expected, and that, having plenty of conduit space, it is almost as economical to place cables of 400 pairs capacity initially.

Relative Costs of Cable and Distributing Wires:—It is not considered economical to place cable unless there will be at the ultimate time more than ten circuits in the territory to be served. When the ultimate requirements justify a 15 pair cable, but the initial needs are small, distributing wire should be employed until four circuits have been installed. When more than four circuits are required, the distributing wire should be replaced by cable.

The number of pairs of each style of wire construction which justify the use of a 50 pair 22 gauge cable is as follows, the annual charges on the wire for the number of pairs given being equal to the annual charges on the cable:

12 pairs No. 14 B. & S. twisted pair copper on distributing brackets.

12 pairs No. 14 N. B. S. waterproof copper on cross-arms.

17 pairs No. 14 N. B. S. bare copper on cross-arms.

Number and Location of Aerial Cable Terminals.—The *location of* terminals is governed by placing them near *the point of* greatest subscriber density, in other words

that the length of the subscribers' drops will be a minimum. The conditions justifying the installation of a terminal on a cable are that the annual charges on the terminal must be less than the annual charges on the distributing wire which would be required if the terminal were not placed. In general, the most economical spacing will be a terminal to every two or three poles.

The terminal capacity should be based on the number of stations which it is expected to serve at the ultimate time rather than lines, on account of the labor charge which would occur in placing an additional terminal and transferring drop wires. The general use of 15 pair terminals is recommended for districts of average density because the small increase in first cost over the 10 pair is warranted on account of the flexibility afforded in the arrangement of cable pairs at the various terminals. The ratio between the two sizes will usually average three 15 pair terminals to one 10 pair terminal.

Multiple Distribution:—The multipling of cable pairs at the various terminals must be made so that any terminal may not become clogged by having all the pairs which are tapped out at it in use at other terminals, and to prevent pairs remaining dead because unavailable at points where they might be used. Fig. 6 shows a guide for tapping out fifteen pair terminals from a 50 pair cable. To apply this guide to cables of larger size, each 50 pair section should be considered as an individual cable. It should be borne in mind, however, that there is no general scheme of multipling that will fit every case, as local conditions will determine which terminals will overlap and the general scheme adopted must be modified according to these conditions.

Points of Cable Relief:—Detail methods of cable relief do not enter into the preparation of cable plans, the point which it is necessary to observe being only to so arrange the multipling as to provide at least one point of relief, by means of a new cable, without disarranging party lines and *consequent number changing.*

The most direct method of relief is to parallel the existing *cable with another* similar cable to which is transferred

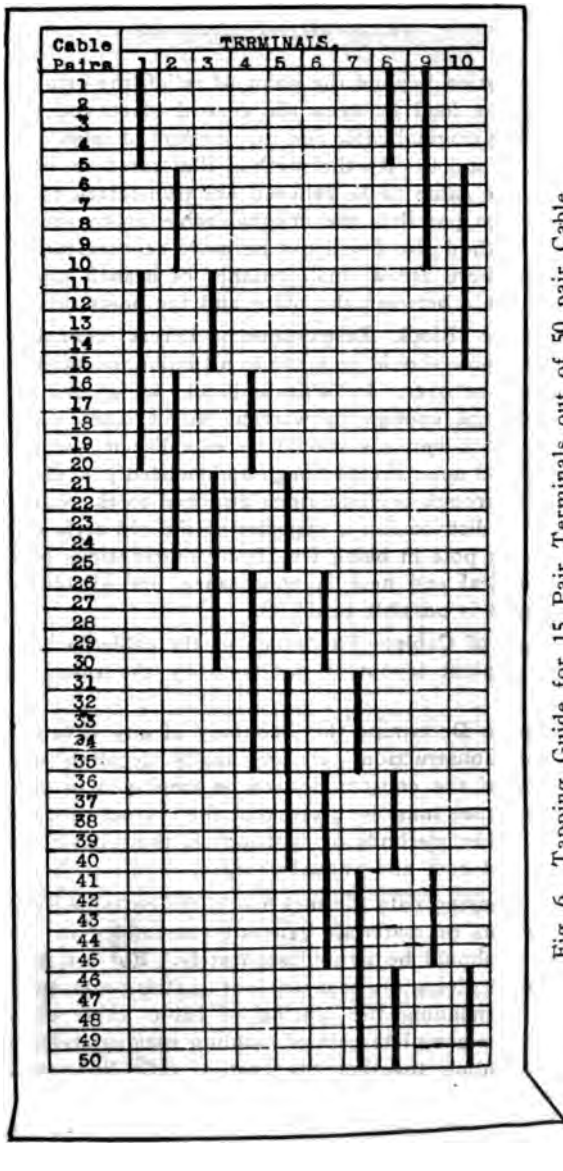


Fig. 6. Tapping Guide for 15 Pair Terminals out of 50 pair Cable.

the distribution beyond the point of relief, the original cable carrying the load between the central office and the relief point. The original cable and this method of relief are shown in Figs. 7 and 8. By the method illustrated in Fig. 9, the taps on the cable to be relieved are transferred to the new cable, which parallels the original cable up to the point of relief. Method No. 2 will not be more economical than No. 1, unless there are a small number of branch taps on the original cable between the office and the point of relief.

Interior Block Distribution: — Direct connection by means of cable should be made to all buildings having fifteen telephones or over. In business blocks which are not large or substantial enough to warrant direct cable connection, interior block systems should be established, the terminals being placed upon the buildings and twisted pair distributing wire run through bridling rings attached to the walls. This method of distribution is superior to the old style circle top distributing pole in being free from interruptions of service, is economical and neat in appearance, and should be used wherever it is possible to do so.

Gauge of Cable:—The gauge of the cable to be used in the cable plant layout is governed by the rules given in Chapter I.

How to Determine the Economy of any Given Plan or Type of Construction:—Before finally deciding upon the character of the construction to be employed in any given case, assurance must be given that the system recommended is of all other methods of distribution, the most economical in both first cost and annual charges.

In preparing data for such work, the costs of elementary combinations of materials generally assembled in construction work should be figured separately. For instance, with a cost sheet giving the cost per foot to string messenger wire complete, including the placing of cable, cable clips, etc., and with the complete cost of building various styles of pole line; by adding together the cost of pole line, messenger wire and cable, the complete cost of a unit length of any style of aerial cable may be obtained. For data on the cost of telephone cable work see Chapter VIII.

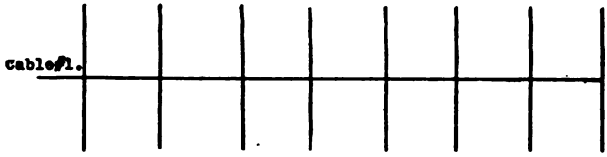


Fig. 7. Original Cable.

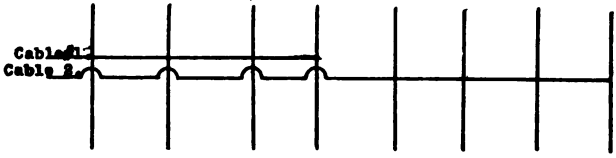


Fig. 8. Cable Relief-Method No. 1.

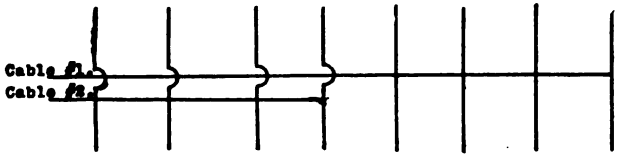


Fig. 9. Cable Relief-Method No. 2.

In comparing costs, the critical factor is the annual charge, meaning by this term the total of the interest and taxes on the sum invested, the maintenance expense requisite in keeping the work in first class operative condition, and the sum set aside annually for what is known as depreciation to cover any possible changes in the art as well as wholesale replacement when the plant is worn out beyond ordinary repairing. Annual charges are a varying percentage of the first cost, depending upon the durability and permanency of the construction. Fig. 10 shows graphically the varying annual charges for the different kinds of construction usually employed in telephone work, the different elements considered in making the annual charge being discussed in Chapter VIII.

In comparing plans with one another the accumulated annual charges are compared, but in the case of materials having different lengths of life, these annual charges may be distributed through the several years in a relatively different manner. For such cases it is necessary to compute the present worth of the charges falling due in the various years in order to bring them to an equal basis of comparison. By the present worth of a charge due at any future period, we mean that sum which if put now at simple interest, will amount to the charge in that number of years. In one plan, for example, a special expense may be incurred in the sixth year, while in other plans a special expense of similar amount may be incurred in the fourth year. Other things being equal, the first plan is to be preferred over the second because of the postponement of the expenditure, in other words, because the present worth of the annual charges is less.

A comparison of the annual charges on a fifty pair, 22 gauge cable and various kinds of wire construction shows that by the time we have 17 pairs of bare copper or 12 pairs of insulated copper in place, we are paying out each year on them a sum which would cover the same charges on the cable. We therefore figure that the cable is the cheaper form of construction because of the larger capacity for the same expenditure.

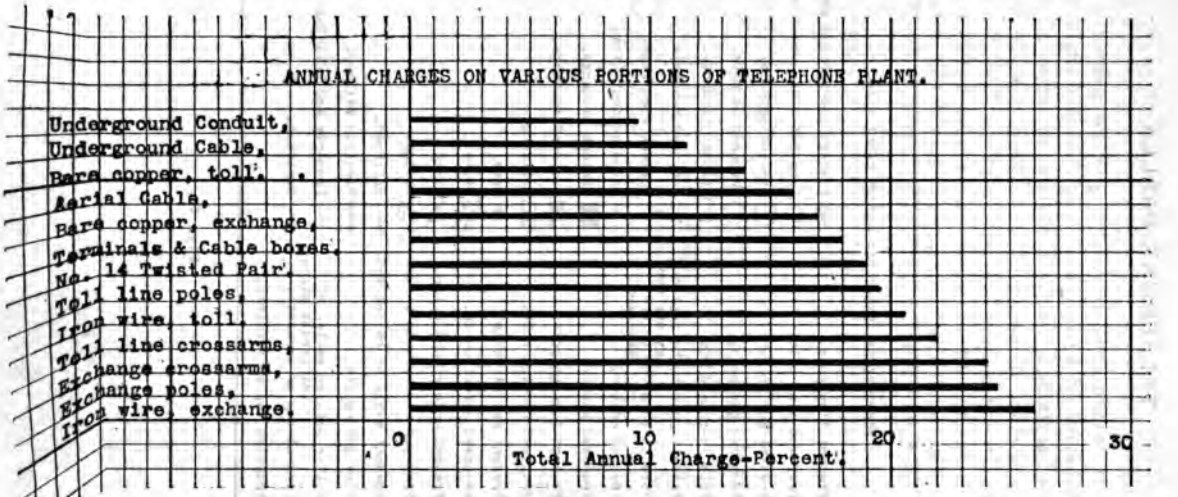

ANNUAL CHARGES ON VARIOUS PORTIONS OF TELEPHONE PLANT.
Underground Conduit.
Underground Cable.
Bare copper, toll.
Aerial Cable.
Bare copper, exchange.
Terminals & Cable boxes.
No. 14 Twisted Pair.
Toll line poles.
Iron wire, toll.
Toll line crossarms.
Exchange crossarms.
Exchange poles.
Iron wire, exchange.
0
10
20
30
Total Annual Charge-Percent.

Fig. 10.

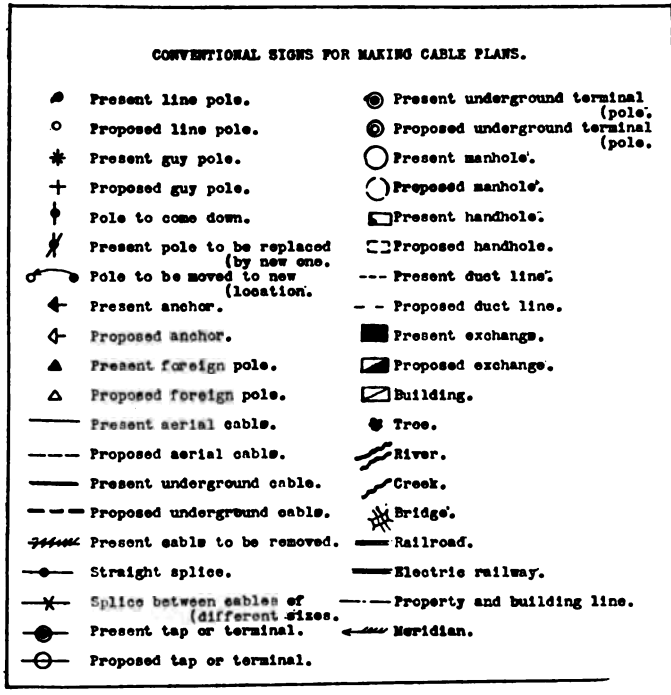

CONVENTIONAL SIGNS FOR MAKING CABLE PLANS.
Present line pole.
Proposed line pole.
Present guy pole.
Proposed guy pole.
Pole to come down.
Present pole to be replaced (by new one.
Pole to be moved to new (location.
Present anchor.
Proposed anchor.
Present foreign pole.
Proposed foreign pole.
Present aerial cable.
Proposed aerial cable.
Present underground cable.
Proposed underground cable.
Present cable to be removed.
Straight splice.
Splice between cables of (different sizes.
Present tap or terminal.
Proposed tap or terminal.
Present underground terminal (pole.
Proposed underground terminal (pole.
Present manhole.
Proposed manhole.
Present handhole.
Proposed handhole.
Present duct line.
Proposed duct line.
Present exchange.
Proposed exchange.
Building.
Tree.
River.
Creek.
Bridge.
Railroad.
Electric railway.
Property and building line.
Meridian.

Fig. 11.

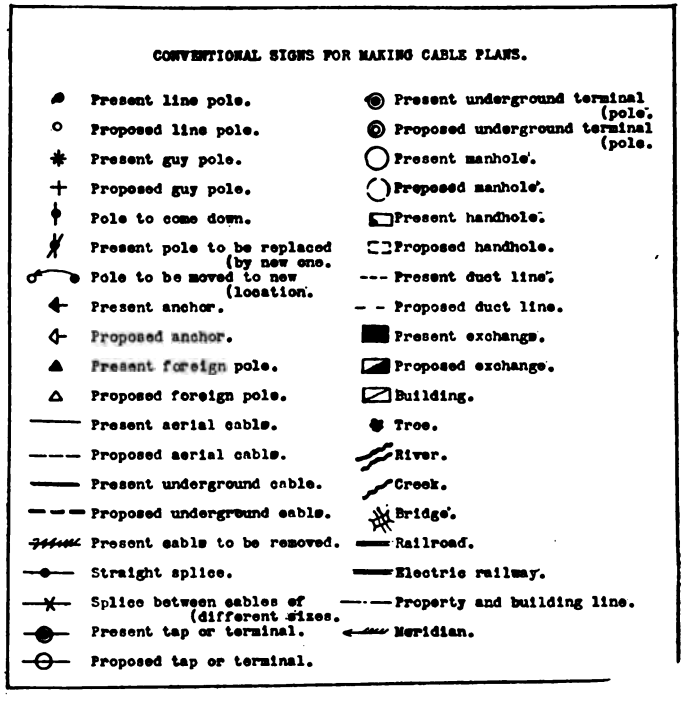

CONVENTIONAL SIGNS FOR MAKING CABLE PLANS.
Present line pole.
Proposed line pole.
Present guy pole.
Proposed guy pole.
Pole to come down.
Present pole to be replaced (by new one.
Pole to be moved to new (location.
Present anchor.
Proposed anchor.
Present foreign pole.
Proposed foreign pole.
Present aerial cable.
Proposed aerial cable.
Present underground cable.
Proposed underground cable.
Present cable to be removed.
Straight splice.
Splice between cables of (different sizes.
Present tap or terminal.
Proposed tap or terminal.
Present underground terminal (pole.
Proposed underground terminal (pole.
Present manhole.
Proposed manhole.
Present handhole.
Proposed handhole.
Present duct line.
Proposed duct line.
Present exchange.
Proposed exchange.
Building.
Tree.
River.
Creek.
Bridge.
Railroad.
Electric railway.
Property and building line.
Meridian.

Fig. 11.

In planning work it should be remembered that investment in plant account must be followed by increase of revenue or decrease in maintenance or operating expense in order to show a profit. In the case of increased revenue, this sum should aggregate thirty per cent. in order to justify the expenditure entailed by new construction.

Future Work and Revisions:—While the cable plan has for its basis an estimate of the amount of business expected five years hence, the territory covered by the plan should be kept under observation, and additional plant installed as required.

Conventional signs for the representation of cables, terminals, and other information on cable plans are shown in Fig. 11. One convenient feature of these symbols is that the signs used to denote existing plant are similar to those employed for proposed construction, hence the changes from proposed to installed plant can be easily made on the maps.

CHAPTER III.

CABLE CONSTRUCTION.

In constructing the cable part of a telephone plant, the greatest care must be taken to avoid work not of a permanent character. The employment of methods of construction not standard, or the skimping of materials in the effort to lessen the initial cost of construction, should never be permitted. The methods of construction described and illustrated herewith are representative of the best modern practice, and will prove economical in the long run for the sum invested.

Pole Lines:—Pole lines on which cable is placed may be constructed of 30 foot poles, but all poles should be of such length as to give the cables the clearance required by local municipal regulations covering this point. Cables should clear obstacles, electric light or power wires by at least 4 feet.

Poles should be graded so as to avoid changes of more than 5 feet in the level of the cables on adjacent poles.

Size of Messenger Wire:—All 100 pair 22 gauge and 50 pair 19 gauge and smaller cables should be suspended with what is known as 10,000 pound messenger wire (⅜ in. diameter). All larger cables should be suspended with what is known as 16,000 pound messenger wire (7/16 in. diameter). All messenger wire used for the suspension of cables should comply with the following specifications:

Specifications for Messenger Wire:—The messenger wire shall be composed of seven (7) galvanized steel wires laid up as specified below. The wires composing the strand shall be free from scales, inequalities, flaws or other imperfections. Each wire shall be of circular section with a uniform diameter, and shall be drawn in one continuous length and be free from factory joints. The wires shall be well galvanized in accordance with standard specifications for *the galvanizing of iron* and steel. A section of the com*oleted messenger wire* shall conform to the mechanical re*uirements set forth in* Table IV.

TABLE IV.

REQUIREMENTS FOR MESSENGER WIRE.

	WIRE			MESSENGER WIRE			
				Breaking weight	Per cent. Elongation		Lay in
Size.	Diameter in inches			pounds.	in 2 feet. inches		
	Required.	Max.	Min.	Minimum.	Max.	Min.	Max.
10,000 lb.	.120	.124	.116	11,500	17	4.5	4.5
16,000 lb.	.144	.150	.138	18,000	15	4.0	5.0

Attachment of Messenger Wires to Poles:—Many different types of messenger suspension clamps are on the market. The "L" clamp, shown in Fig. 12, loaned by the Hallett Iron Works, has remained the favorite with many companies for a number of years. A somewhat more desirable form of clamp is that illustrated in Fig. 13, loaned by the Kellogg Switchboard and Supply Company. Fig. 14

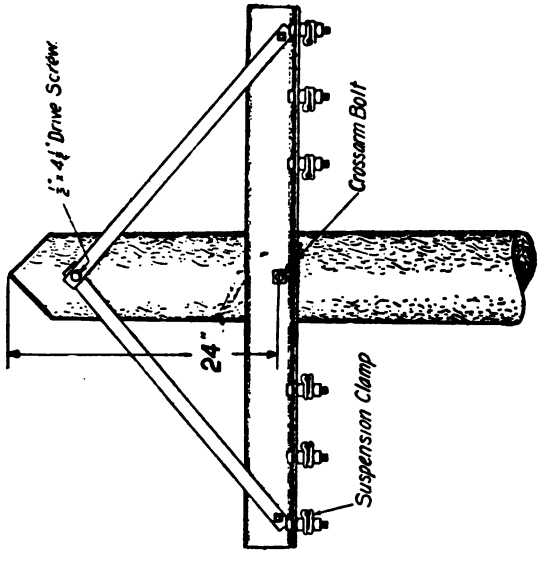
Fig. 12.

Fig. 13.

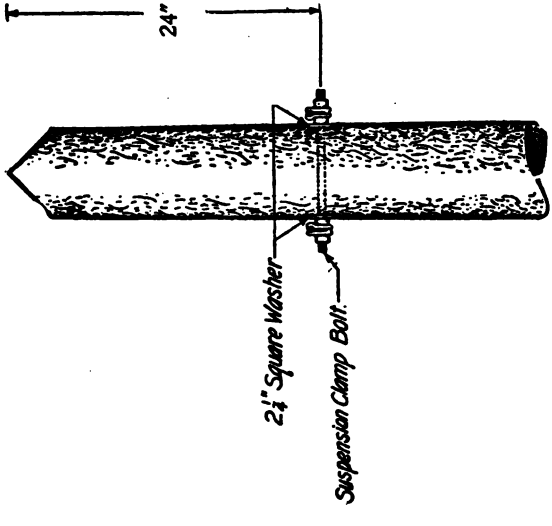
Fig. 14.

Fig. 12. "L" Messenger Suspension Clamp.
Fig. 13. Messenger Suspension Clamp.
Fig. 14. Messenger Suspension Clamp.

shows a similar clamp, manufactured by the Hallett Iron Works. The method of using this clamp for the attachment of messenger wires to poles is as follows: A hole 11/16 of an *inch in diameter* is bored through the center of each pole *24 inches below* its apex and at right angles to the lin *This distance* is allowed for the attachment of termi



METHOD OF SUPPORTING MESSENGERS ON CABLE CROSSARMS
Fig. 16.



METHOD OF SUPPORTING MESSENGERS ON POLES.
Fig. 15.

and brackets for distribution purposes. A suspension clamp is secured to the pole at this place by means of a ⅝ inch machine bolt threaded back about 4 inches at each end, and of sufficient length to admit of the attachment of a suspension clamp at either end. Table V. shows the proper length of bolt to use for different sizes of poles.

TABLE V.

LENGTH OF SUSPENSION BOLT TO USE FOR DIFFERENT DIAMETERS OF POLES.

Poles	5 to 6 in. diameter,	12 in. bolt.
Poles	7 to 8 in. diameter,	14 in. bolt.
Poles	9 to 10 in. diameter,	16 in. bolt.
Poles	11 to 12 in. diameter,	18 in. bolt.

A 2¼ inch square washer is placed under the nut on each side of the pole, and the bolt securely locked to the pole before the clamp is applied. Fig. 15. When the first cable is placed the messenger should be fastened to the street side of the pole, and the second messenger be attached to the sidewalk side of the pole.

When more than two cables are to be strung on a pole line, steel cable crossarms, placed 24 inches below the apex of the pole, should be used for messenger suspension, the messenger wires being attached to the crossarm by means of suspension clamps of the type last described, and ⅝ by 3 inch bolts, as shown in Fig. 16.

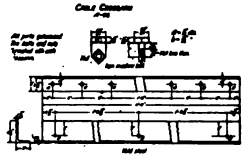


Fig. 17.

Height of Messenger Wire:—On leads without bare wires *on crossarms* the height of the messenger wire should *be as specified* above and as shown in Fig. 15 and 16. C *leads with bare* wires on crossarms the center of the lo

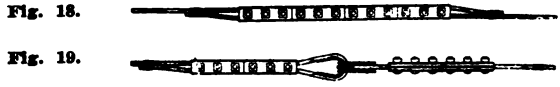


Fig. 18. Method of Splicing Messengers of Same Diameters.

Fig. 19. Method of Splicing Messengers of Different Diameters.

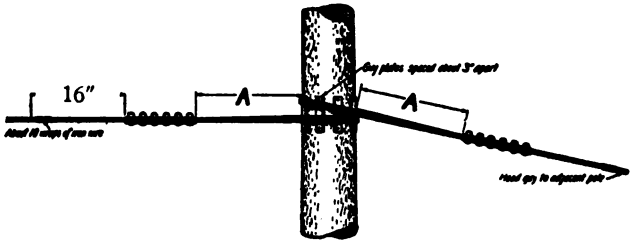


Fig. 20. Method of Dead Ending Messenger and Attaching Head Guy to Adjacent Pole.

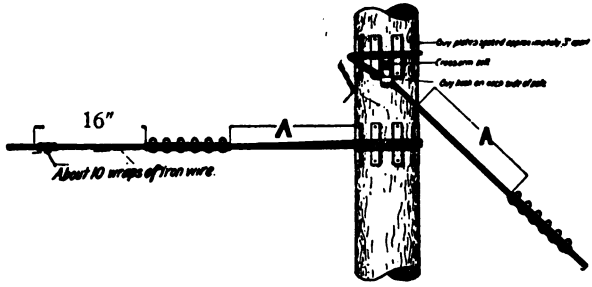


Fig. 21. Method of Dead Ending Messenger and *Attaching* Anchor Guy.

ultimate crossarm should be considered as being the apex of the pole. In all cases a clearance of at least 20 feet above the ground at street crossings, and 25 feet at railroad and street railway crossing, should be secured.

Sag of Messenger Wire:—The minimum sag for messenger wire with cable should be in accordance with Table VI.

TABLE VI. SAG OF MESSENGER WIRE WITH CABLE.

100 foot span.	Minimum sag	2	feet.
115 foot span.	Minimum sag	2½	feet.
130 foot span.	Minimum sag	3	feet.
150 foot span.	Minimum sag	4	feet.

Dead Ending Messengers:—Messengers should be dead-ended by being wrapped twice about the pole and fastened with two guy clamps, as in Fig. 21. All poles on which messengers are dead-ended should be protected from cutting by the strand by means of guy plates or strain plates.

Splicing Messenger Wire:—Messenger wire should be strung in as long lengths as possible in order to avoid splicing. When necessary to make splices, they should be located as close to poles as possible. Figs. 18 and 19 show methods of splicing.

Character of Guy Strand:—All guying of cable leads should be done with strand conforming to requirements for messenger wire. For side guying, ⅜ inch strand is used where the pull is less than 20 feet; if it is greater than 20 feet, or the strain is heavy, 7/16 inch strand is used. Head guys on cable leads should be of the same size as the messenger wire. Line-guying of 7/16 inch messenger wire is done with ⅜ inch stand.

Attaching Guys:—All head guys to adjacent poles should be attached above and close to the messenger as shown in Fig. 20. Anchor head guys at end of messenger should be attached above the messenger as shown in Fig. 21. In order to avoid danger to the anchor by electrolysis all guys attached to anchors should be entirely insulated from any *cable, messenger* or ground wire on the pole. Figs. 21 and *22 show methods* of separating guys and messengers.

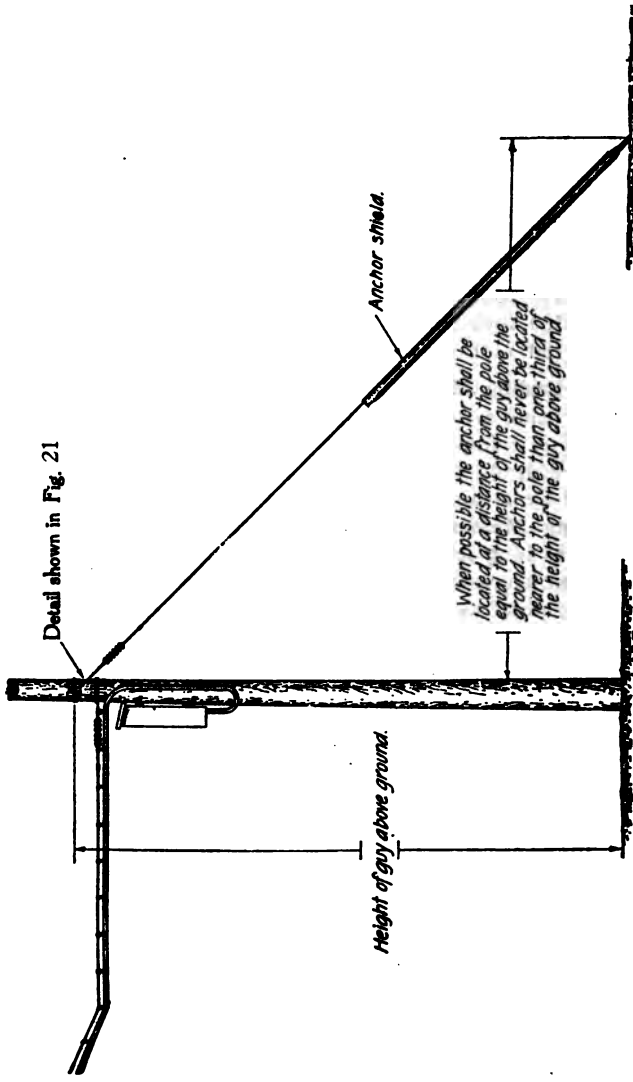

Detail shown in Fig. 21
Anchor shield.
When possible the anchor shall be located at a distance from the pole equal to the height of the guy above the ground. Anchors shall never be located nearer to the pole than one-third of the height of the guy above ground.
Height of guy above ground.

Fig. 22. Location of Anchors for Head or Side Guying of Cable Leads.

All side guys should be attached above and as close to the messenger as possible. If the side guy is anchored close to the pole so that the guy cannot clear the cables, the guy should be placed below and as near to the messenger as possible.

Clearance:—In all cases guys should be so placed as to afford a clearance of at least 18 feet over driveways and 8 feet over walks, and in accordance with any local municipal regulations that may be in force covering this point.

Method of Fastening:—Guys should be wrapped twice about the pole and fastened with guy clamps. The distance at which the guy clamps are placed from the pole, designated on all drawings of guying methods as "A", should not be less than 1 foot for poles under 8 inches diameter, 1½ feet for poles between 8 and 12 inches diameter, and 2 feet for poles over 12 inches diameter. With ⅜ inch guy strand one clamp only is required at each end of the guy, with 7/16 inch guys, two clamps should be used. The turns of guy strand should not be crossed on the pole except where guy hooks are used. Figs. 23 and 24. Single bolt guy hooks are used where messengers are head anchor guyed, Fig. 21. Where other guys cannot be held from slipping on the pole, double bolt guy hooks are used as in Fig. 24. In this case the guy strand is crossed once on the side of the pole away from the guy. Whenever the guy strand passes through the eye of an anchor rod, ½ inch thimbles should be used for ⅜ inch strand, and ⅝ inch thimbles for 7/16 inch guys. The ends of the guy strand should extend about 16 inches beyond the guy clamp and be wrapped with about 10 turns of iron wire, as shown in Fig. 25.

Guy Hooks:—Double bolt guy hooks may be used to prevent ⅜ inch guys from slipping on the pole. Fig. 24.

Single bolt guy hooks are used where messengers are dead-ended and head anchor guyed, or side anchor guyed. Fig. 21.

Double bolt guy hook should be fastened to the pole by means of ⅜ by 4 inch lag screws. Single bolt guy hooks are secured to the pole by means of a crossarm bolt. Fig. 26 shows a strain plate and Fig. 27 a guy hook.

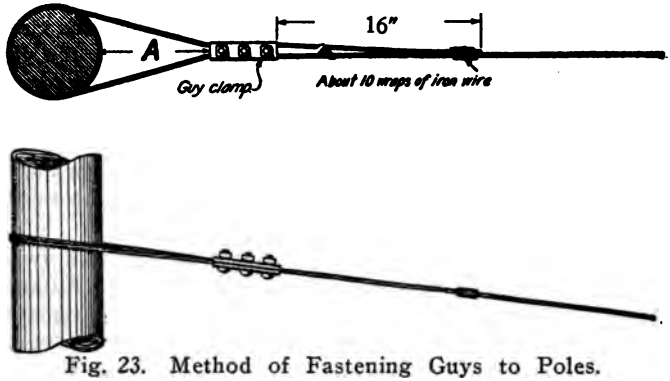


Fig. 23. Method of Fastening Guys to Poles.

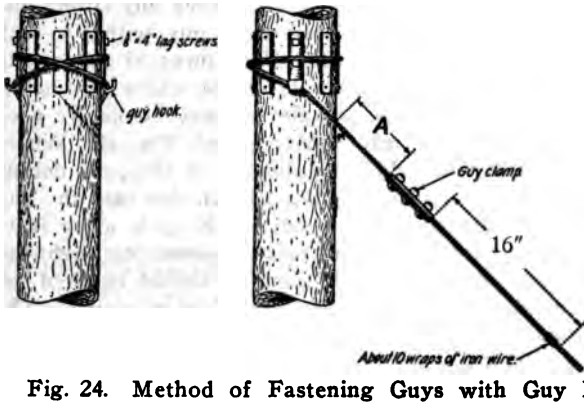


Fig. 24. Method of Fastening Guys with Guy Hooks and Guy Plates.

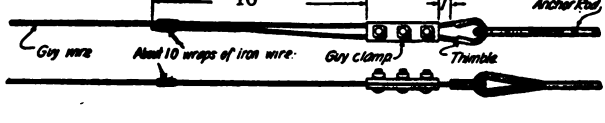


Fig. 25. ***Method of Fastening Guys to Anchors.***

Guy Plates:—All poles on which messengers are dead-ended or to which 7/16 inch guys are attached should be protected from cutting by the strand by means of guy plates

Fig. 26. Strain Plate.

as shown in Figs. 20, 21 and 24, or by means of strain plates of the type shown in Fig. 26. Guy plates should be spaced approximately 3 inches apart when placed at the top of the

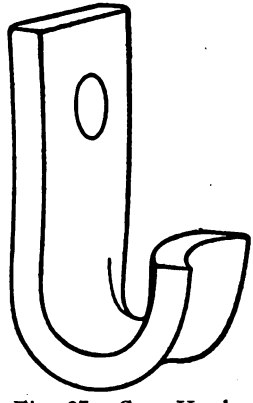


Fig. 27. Guy Hook.

pole and 5 inches apart at the butt, and should be fastened *with 6 penny* wire nails. Strain plates as shown in Fig. *may be employed* in place of the guy plates if desired.

Methods of Guying:—The following methods of guying are in accordance with the best modern practice.

Head Guys to Adjacent Poles:—Head guys from the top of a pole to the butt of an adjacent pole are attached to the latter not less than 7 feet from the ground.

Anchor Head Guys:—With 200 pair 22 gauge cable, 100 pair 19 gauge cable, or larger, all head guys are anchor guys. Figs. 28 and 21. With smaller cable, guys are dead-ended to adjacent poles. Fig. 29.

With cables larger than 100 pair 22 gauge or 50 pair 19 gauge where the distance from the pole to the anchor is less than 2/3 the height of the guy from the ground to the point of attachment on the pole, 7/16 inch strand is used. With 50 pair 22 gauge cable, or 25 pair 19 gauge cable, or smaller, 3/8 inch guy strand is used.

Where Messenger and Cable Terminate at the Same Pole:—On pole leads without cable crossarms the messenger and cable end on the same pole. With 100 pair 22 gauge or 50 pair 19 gauge cables or smaller the messengers are head guyed as shown in Fig. 29. If there is a pole beyond the cable terminal pole the terminal pole is guyed to it, otherwise an anchor is placed. Fig. 28. If an anchor cannot be placed, the terminal pole is securely ground-braced and the messenger at the adjacent pole line guyed to the terminal pole as shown in Fig. 30.

Anchor guys are placed at the end of messengers carrying 200 pair 22 gauge or 100 pair 19 gauge cable or larger. Fig. 28. Where messengers with 200 pair 22 gauge or 100 pair 19 gauge cables and larger cannot be anchor guyed, double head guys are employed as shown in Fig. 31.

Where Messenger and Cable Terminate on Adjacent Poles:—On pole leads with cable crossarms the messenger and cable end on adjacent poles, the messenger being carried ahead one span beyond the end of the cable. The messenger is guyed as above described.

Terminating Two or More Messengers:—Except at *underground terminal poles*, each messenger terminates at *a separate pole, which* is head guyed as described above. *Fig. 32.*

Fig. 28.

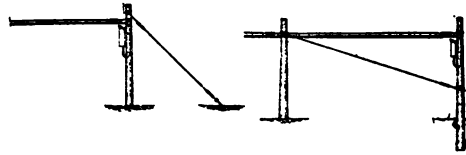


Fig. 29.

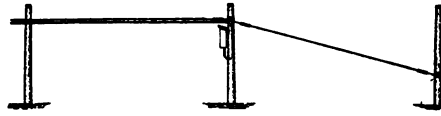


Fig. 31.

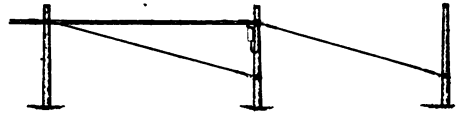


Fig. 32.

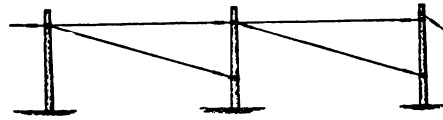


Fig. 33.

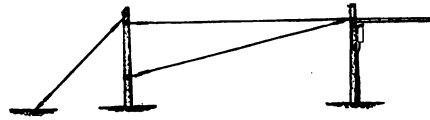


Fig. 28. Method of Terminating Messengers Carrying 200 Pair 22 Gauge or 100 Pair 19 Gauge Cables or Larger.

Fig. 29. Method of Terminating Messengers Carrying 100 Pair 22 Gauge or 50 Pair 19 Gauge Cables or Smaller.

Fig. 30. Method of Guying Where Terminal Pole Cannot be Head Guyed.

Fig. 31. Method of Guying Where Messenger Cannot be Anchored.

Fig. 32. Method of Terminating Two or More Messengers on the Same Lead.

Fig. 33. Method of Guying at Junction of Aerial and Underground Cables.

At Underground Terminal Poles:—At all underground terminal poles, the messenger is carried back at least one span where possible, and guyed as described above. The terminal pole is head guyed in all cases if possible. Fig. 33.

Guying at Intermediate Points in a Long Lead:—On long cable leads with a straight section of 20 or more poles, every tenth pole is head guyed in both directions to safeguard the line. At these points a guy clamp is placed on each side of every suspension clamp, in order to prevent the messenger from pulling through.

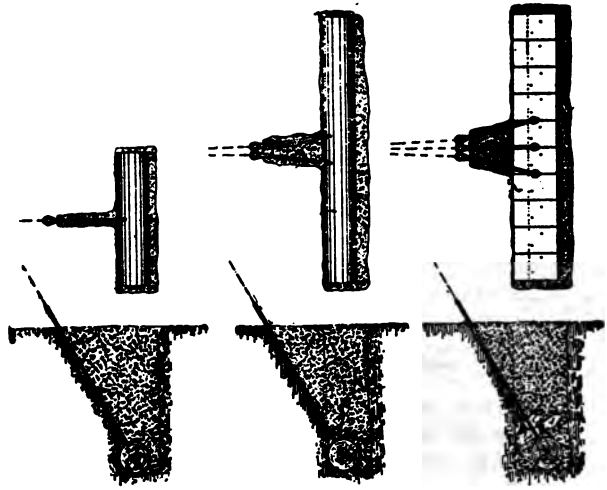


Fig. 34. Method of Setting Anchor Logs.

Mechanical Protection:—Guys are protected at the ground by means of iron anchor shields as in Fig. 22. These shields consist of steel boiler tubes 2½ or 3 inches in diameter, having a length of about 10 feet. They are usually painted inside and out with black asphaltum paint.

Anchors:—The style of anchors used on cable leads may be of the standard log form shown in Fig. 34, or some type of patented anchor, but care should be taken that the anchor employed is capable of holding all strains which may be

placed upon it. Where anchor logs are used they should be set in the ground at least 6 feet deep, and never less than 4 feet deep. Standard 5/8 inch guy rods should be used with 3/8 inch guy strands, and 1 inch rods for 7/16 inch guys. Anchors should be located at a distance from the pole equal to the height of the guy above the ground, and never be located nearer to the pole than 1/3 of the height of the guy above ground. Fig. 22. The eyes of all anchor rods should clear the ground by about 10 inches, so as to permit inspection.

Fig. 35. Cable Rollers.

Cable Erection:—In installing aerial cable it is usual to stretch a "leading-up" wire from the butt of a guy stub or adjacent pole to the first pole on which the cable will be placed. This leading-up wire serves as a guide and support for the cable while it is being pulled into place. The cable reel is supported on an axle of such height as will cause it to clear the street about 6 inches, so that it may easily and freely revolve. The reel should be placed so that the cable will unroll from the top of the reel. The pulling rope is attached to the cable by means of a cable grip and swivel hook in a manner similar to that described for methods of drawing in underground cable. The cable may be pulled by hand, horse power, or engine. While the cable is being drawn into place, it may be supported on cable rollers or trolleys of the type shown in Fig. 35, loaned by the Specialty Device Company. Other methods of aerial cable erect

do not employ cable trolleys, but attach the cable hangers to the cable and leading up wire as the cable is paid out, the hangers moving along the messenger as the cable is pulled. This method requires that a man be stationed at each pole to lift each cable hanger off the messenger wire as it passes the suspension clamp.

Fig. 36. Aerial Cable Ring.

Cable Hangers:—The various forms of cable hangers in use today may be divided into the following classes:

(a) Standard marlin cable clips.

(b) Forms of hangers making use of a metal band for the suspension of the cable.

(c) Metal rings.

Marlin clips have remained the standard for many companies because of their known reliability when made up to standard specifications, ease and economy of application, and because the bonding of cable to the messenger wire, (which is claimed to be an accomplishment of the metal hanger), is best taken care of by means of regular bonds placed at specified intervals. There are, however, many satisfactory metal band clips on the market.

One of the best types of metal rings is illustrated in *Fig. 36, loaned by the* Cameron Appliance Company. This *ng is made in six* different sizes, from 1¾ inch to 3½

inches inside diameter, and is exceptionally strong, because fastened to the messenger wire at two points. In using rings of this type no cable rollers are necessary, as the cable can be pulled directly into the rings from the reel, and the time saved in installation is considerable. In addition, the life of a ring of this description is as great as that of the messenger wire which supports it, and renewals are not necessary. The construction is very strong and looks exceptionally neat when in place. There is undoubtedly a wider field of usefulness for this type of hanger than is given to it at the present time.

As marlin cable hangers are most familiar to the majority of telephone companies, their use alone is described and illustrated in the following pages. All marlin cable clips employed for the suspension of aerial cable should conform to the following specifications:

Specifications for Marlin Cable Hangers:—Each complete hanger shall consist of a galvanized steel wire hook assembled with a loop of marlin, as shown in Fig. 37. The

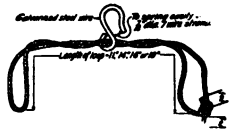


Fig. 37. Marlin Cable Clip.

hook shall be made of steel wire, which after galvanizing, shall have a diameter of 0.148 inches. The diameter of any hook accepted shall not exceed 0.152 inches, nor be less than 0.144 inches. The wire shall be cylindrical in form and free from scales, flaws, splints, or other imperfections. The openings in the hook shall be of the dimensions specified in Table VII.

TABLE VII. DIMENSIONS OF OPENING IN HOOK OF MARLIN CABLE HANGERS.

Length of loop Attached to hook inches	Dimensions of opening inches	ALLOWABLE VARIATION	
		Will admit circular bar having diameter of	Will not admit circular bar having diameter of
11	9/32	17/64 inches	19/64 inches
14	11/32	21/64 inches	23/64 inches
16	13/32	25/64 inches	27/64 inches
19	13/32	25/64 inches	27/64 inches

Hooks shall not be sprung in determining dimensions. The hooks shall be well galvanized in accordance with standard specifications for the galvanizing of iron and steel.

The galvanized hook shall not spring open more than one-sixteenth (1/16) of an inch when subjected to a load of one hundred (100) pounds and shall return to within one-sixty-fourth (1/64) of an inch of its original position upon the removal of the load.

The marlin shall be three (3) ply and of the best quality, pure, double dressed American hemp, and shall be thoroughly saturated with Southern Pine Tar. The length of loop shall be 11, 14, 16, 19 inches, as specified.

The knot shall be drawn tight. The knot ends shall be at least one-half (½) inch in length.

The marlin loop shall stand a strain of at least three hundred and thirty (330) pounds without breaking.

Attaching Cable Clips:—When marlin cable clips are used for the suspension of aerial cables from the messenger wire, they shall be spaced 14 inches apart for 200 pair 22 gauge or 100 pair 19 gauge cable or larger, and 20 inches apart for smaller cables. Fig. 38. Double hangers should be placed on each side of the pole or cable crossarm 8 inches *from the suspension clamp* bolt, Fig. 38, and also at the ends *of all splices. Fig. 39.*

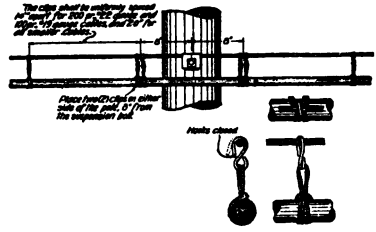


Fig. 38. Method of Attaching and Spacing Marlin Cable Clips.

To attach cable hangers to the cable the double loops are passed around the cable and the hook drawn up through the loops as shown in Fig. 38. The hooks should be closed or pinched after they are placed on the messenger.

Cable should be hung straight and without any sag between the hangers. All kinks and bends in the cable should be smoothed out as the cable hangers are applied. Fig. 38.

The length of the cable hanger loops which should be used for different sizes of cables is as follows:

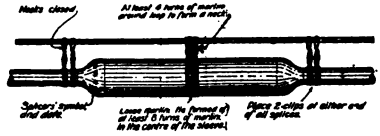


Fig. 39. Method of Supporting Splices on Messengers.

TABLE VIII. LENGTH OF CABLE HANGER LOOPS.

Length of Loop Inches.	CABLE			
	No. 16 ga. .072 cap.	No. 19 ga. .054 cap.	No. 19 ga. .08 cap.	No. 22 ga. .069 cap.
11	.....	25	25-50	25-50
14	25	50	100	100
16	50	100	150-200	150-200
19	100	150-200	300	300-400

Turning Cables on Messenger Wire:—Whenever necessary to make turns in the cable, care should be taken to make all bends of sufficient radius to prevent injury to

cable, this dimension never being less than 18 inches. Suspension clamps should be placed at the crossing of the two messenger wires, and the cable be suspended with hangers of extra length at bends. Fig. 40.

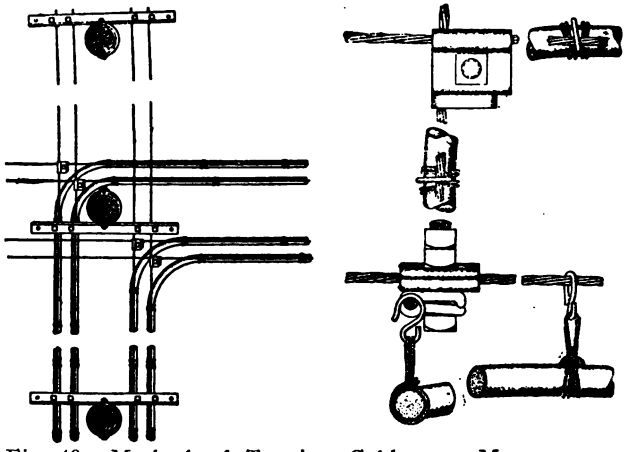


Fig. 40. Method of Turning Cables on Messengers.

Cable Splicing Material:—All material used in splicing cable shall be in accordance with standard specifications.

Wiping metal should be composed of 40 per cent. by weight of pure tin and 60 per cent. of pure lead. Zinc or other impurities in wiping metal make it hard to work.

Sealing compound should be composed of 10 parts by weight of heavy rosin oil and 90 parts of approved waterproof, semi-elastic insulating compound, which when melted will readily flow into the lead sleeve and about the wires, adhering tenaciously to the wires and will not be sufficiently affected by exposure as to endanger the seal of the terminal.

Lead sleeves should be made of pure lead. The thickness of the lead sleeves should be ⅛ of an inch when the *inside* diameter of the sleeve is 3 inches or less, and 5/32 of *an inch when the inside* diameter is more than 3 inches. The *izes of sleeves to be* used for different size cable splices are *follows:*

TABLE IX.

LENGTHS AND SIZES OF LEAD SLEEVES.

For Straight Splices.

No. of Pairs.	No. 19 Gauge Cable. Inside Dia. Inches.	Length. Inches.	No. 22 Gauge Cable. Inside Dia. Inches.	Length. Inches.
10	1	16	1	16
15	1	16	1	16
25	1½	16	1½	16
50	2	16	2	16
75	2½	16	2½	16
100	3	16	2½	16
150	3	18	2½	16
200	3½	18	3	18
300	4½	22	3½	18
400	.....	....	3½	22

TABLE X.

LENGTHS AND SIZES OF LEAD SLEEVES.

For Three Way or "Y" Splices.

No. of Pairs.	No. 19 Gauge Cable. Inside Dia. Inches.	Length. Inches.	No. 22 Gauge Cable. Inside Dia. Inches.	Length. Inches.
10	1	16	1	16
15	1½	16	1½	16
25	1½	16	1½	16
50	2½	16	2½	16
75	3	16	3	16
100	3½	18	3½	18
150	4	18	4	18
200	4½	22	4	18
300	4½	22	4½	22
400	.....	....	4½	22

TABLE XI.

LENGTHS AND SIZES OF LEAD SLEEVES.

For Potheads.

No. of Pairs.	No. 19 Gauge Cable. Inside Dia. Inches.	Length. Inches.	No. 22 Gauge Cable. Inside Dia. Inches.	Length. Inches.
25	2	20	2	20
50	2½	20	2½	20
100	3½	24	3½	24
150	4	26	3½	26
200	4½	30	4	26
400	.....	....	4½	26

For splicing intermediate sizes a sleeve for the next larger size of cable should be used. For splicing cables larger than are given above, sleeves should be used having a length equal to about 8 times the outside diameter of the cable and with an inside diameter about 50 per cent. greater than the outside diameter of the cable.

Split sleeves should be used in the following cases: (a) Where cables form a double "Y"; (b) where on account of the position or bends in the cables it is impossible to slip a sleeve back and run it up in place again over the splice when it is completed; (c) where in splicing a branch cable into a working cable, only the conductors to be spliced are cut, the other conductors remaining in service and the old sleeve not being used again on making the new splice.

Kinds of Splices:—There are two kinds of splices, known as Straight and Bridge Splices. Potheads are used for terminating dry core cables in cable boxes.

Straight Splices:—(a) Where all conductors of two cables are spliced together, each joint of conductors being composed of two wires; (b) when the conductors of one cable are spliced into a cable containing a larger number of conductors, part of which are left "dead," each joint of conductors being composed of two wires; and (c) where either part or all of the conductors of two or more cables

are spliced into part or all of the conductors of another cable, each joint of conductors being composed of two wires and the conductors not spliced, being left "dead."

Bridge Splices:—(a) When all the conductors of three or more cables are spliced together, each joint of conductors being composed of the same number of wires; (b) when all the conductors of a cable are spliced into a cable composed of one-half, one-quarter, etc., the number of the conductors, each joint of conductors being composed of like number of wires.

Instructions for Making Splices:—If it is possible splices should be finished and soldered up the day they are begun. If the weather be dry, the splice may be left open over night, provided it is protected from moisture by having a rubber blanket or other suitable moisture-proof substance wrapped around it. However, work on a splice in a moist place should be continued until completed. It is recommended that the splice be boiled out after splicing every 50 pairs, when moisture is likely to get into the splices. When a cable is cut it should be thoroughly dried and its ends sealed tight with solder. Just as much care should be taken with a temporary job as a permanent one.

If moisture has entered the end of a cable or if it is even suspected that it has, a short piece of the cable should be cut off and dipped into hot paraffin. If moisture is present it will be detected by a frying noise. The damp part of the cable should be cut away gradually if it can be spared, and each piece tested for moisture. If the length of the cable will not allow the damp portion to be cut away, the exposed damp portion shall be boiled out and then a portion of the lead sheath of the cable cut and slipped over it and the new exposed part boiled out. This process, known as slipping sheathing, should be continued until all moisture is expelled. Care must be taken not to tear the insulation in slipping the sheath and all joints should be closed by the regular wiped joint. When it is found that there is no more moisture present, the cable should be spliced.

Whenever a cable is cut for any purpose and it is neces*sary to leave the* cable end, it should be thoroughly dri

and sealed with half and half solder. Care should be taken to see that the joint is made just as secure and air tight as if it is to be permanent. Straight and bridge splices are made exactly the same way in both aerial and underground work.

Straight Splices:—The following operations, in their order, are performed in splicing two cables in a straight line:

(1) A light indentation is made in the sheath of each cable with a chipping knife to mark the point at which the sheath is to be removed. A portion of the sheath of each cable for about 4 inches beyond this mark is scraped bright and rubbed with tallow to keep the cable clean during the splicing. The sleeve for a distance of about 4 inches from each end is scraped bright and treated in the same manner. The tallow also acts as a flux in making the joints.

(2) The lead sheath of each cable is cut on the marks above described to a sufficient depth to break readily on bending, and the ends removed. Care must be used in removing the sheath not to injure the insulation.

(3) The core is bound tightly with narrow strips of dry muslin at the ends of the cable sheaths, packing the muslin back under the sheath as much as possible so as to prevent the sheath from cutting the insulation of the conductors.

(4) As soon as possible after removing the lead sheath from the cable, the cable is boiled out with hot paraffin until all the moisture is removed. Paraffin remaining in the core will form a seal to keep all moisture out during the splicing. In boiling out cables great care must be taken that the paraffin is not too hot as when paraffin is very hot, it not only injures the insulation of the cable conductors, but is dangerous to life in that it may take fire. If paraffin be heated so hot that white fumes arise it should be allowed to cool before being used. The paraffin should never be so hot as to injure rubber insulated wire when immersed in it for one minute. In drying or boiling out a cable with paraffin work should always begin at the cable sheath and be toward the center of the splice or end of conductors, so that moisture will not be forced under the lead sheath. The

paraffin is poured on with a ladle, a pan or the pot being used to catch the paraffin which is drained off.

(5) The lead sleeve is slipped over one of the cables and pushed back out of the way.

(6) If several lengths of a cable are to be spliced at successive places, or in making the first splice on any cable, no testing or tagging is necessary and the splice is made without regard to the conductor assignment of the pairs. Pairs in corresponding layers should be spliced together. In all other cases it is necessary to splice according to conductor assignment, and a battery shall be put on one pair of conductors and this shall be picked up by the splicer at the other end. This pair shall be used as a talking pair and the other pairs in the cable be selected in a similar manner and tagged.

When branch splices are made on a working cable, care must be taken not to unnecessarily disarrange the lay of conductors. Particular care must be taken not to nick the wire and not to cut the insulation any more than is necessary. If the insulation be cut it is liable to unwind from the wire, causing crosses in the splice.

When hunting pairs in a working cable of a common battery exchange, a condenser should be connected in series with the knife and head telephone. This is to prevent the switchboard lamps of working lines which are touched from flashing, thus giving signals to the operator. In all tagged splices the extra pair shall be so tagged when a splice is completed that it may be readily accessible in clearing trouble.

(7) The cables are lined up straight and securely fastened, the distance between the ends being about 3 inches less than the length of the lead sleeve.

(8) After the cables are lined up in position, the conductors are bent out of the way at the sheath and then spliced in the following manner:

(9) Starting at the center or lower back side of the cables, a pair of wires from each cable shall be brought together with a partial twist, as shown at 1 in Fig. 41, thus marking by the bend in the pair the point at which the joint is to be made. The insulation shall be removed from both wires beyond the twist, care being taken not to scrape the conductors, a paper sleeve slipped over each wire of one pair of conductors and pushed back out of the way to make room for the joint.

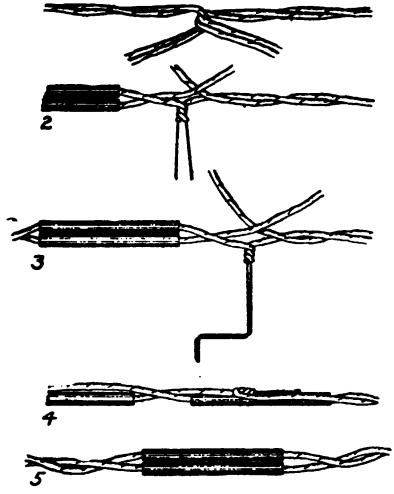


Fig. 41. Method of Making a Twisted Joint in a Straight Splice.

The wires shall be connected by the ordinary twist joint. The like wires from the two pairs to be spliced shall be brought together at the point marked in the bend, and given two or three twists as shown in Fig. 41. The two wires are now to be bent as shown at 3 and twisted together as if turning a crank. The ends of the wires shall be cut off so as to not leave the twisted wires shorter than one (1) inch. The twist shall be bent down along the insulated wire and th

paper sleeve slipped over the joint as shown at 4 in Fig. 41. The completed joint is shown at 5 of Fig. 41.

Care should be taken in picking out pairs to be spliced to take the center pairs first and to arrange the outer pairs about them neatly. The wire joints shall be distributed along the length of the splice in order to keep the splice uniform in size and shape.

(10) When all the wire joints have been made the splice is boiled out again with hot paraffin until all moisture has been expelled. The paraffin should be applied as described before, working toward the center of splice.

(11) The splice (while hot) is wrapped with strips of muslin 2 or 3 inches wide and compressed so as to be admitted into the lead sleeve. The splice must not be compressed so tightly as to cause crosses in it. The muslin must not be boiled in paraffin before wrapping. After the muslin is in place the splice shall be again boiled out with hot paraffin to remove any traces of moisture that may be left.

(12) The lead sleeve is slipped into place before the splice is cool. The ends of the lead sleeve, which should overlap the ends of the cable sheaths about 1½ inches, are beaten down to conform with the cable sheath and a wiped joint carefully made at each end. In making wiped joints, strips of gummed paper are used to limit the flow of solder on the sheath. All wiped joints should be carefully inspected, using a mirror, when necessary, to detect any imperfections in the seal. Fig. 42 shows a completed cable splice.

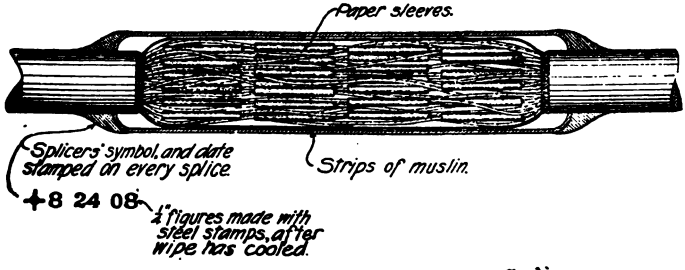

Paper sleeves.
Splicer's symbol, and date stamped on every splice.
+8 24 08
Strips of muslin.
Figures made with steel stamps, after wipe has cooled.

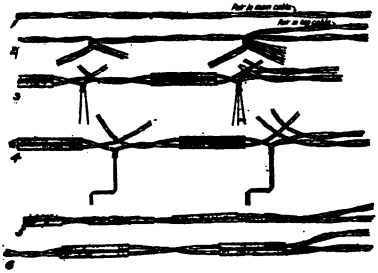
Fig. 42. Completed Cable Splice.

The method of making a joint in cable splices where the size of the conductor is 16 gauge or greater, is the same as for the ordinary splice described above, except that in the process of twisting the conductors together, one wire is taken in each hand and each wire given five turns around the other.

The method of making a straight splice when three cables form a "Y," is generally the same as for splicing cables in a straight line, the ends of the cable being prepared in the same manner. The two cables forming a straight line are secured with the ends of the sheaths a distance apart equal to about 3 inches less than the length of the sleeve. Then the third cable is lashed to one of the other cables (depending upon the direction in which the third cable is to be run) with ends of sheaths even, and directly opposite to that on the single cable.

The method of making a straight splice when four cables form a double "Y" is generally the same as described above. The ends of the cable are prepared in the same manner and the cables lashed together with ends of their lead sheaths opposite each other. Split sleeves shall be used on such splices. The seam of the split sleeve must be carefully soldered, and the ends of the sleeve beaten down to conform to the sheath of the cables and soldered with a wiped joint at both ends. After finishing wiping the ends, the seam should be touched up again to make certain that it is tight.

Bridge Splices:—The method of making a bridge splice is the same as for a straight splice except that the wire joints



ig. 43. Method of Making a Twisted Joint in a Tap Splice.

are made by twisting together like wires of three or more pairs of conductors. Fig. 43 shows the method of making a twisted joint in a tap splice. Fig. 44 shows the method of making a twisted joint for a tap into an old straight splice.

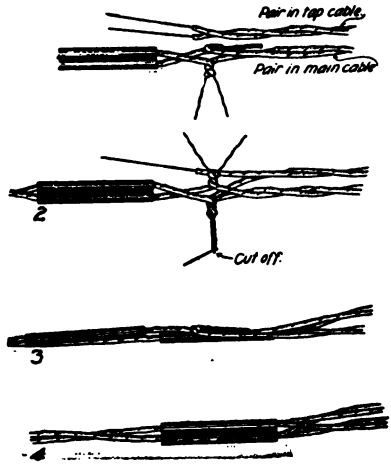


Fig. 44. Method of Making a Twisted Joint for a Tap into an Old Straight Splice.

Potheads:—About 15 inches of sheath shall be removed from the lead cable, and the paper insulated wires thoroughly boiled out with hot paraffin. The lead sleeve shall then be slipped back over the cable, and the wires spliced to the rubber covered pothead wires in the usual manner, using paper sleeves. The splices shall be placed so that no paper sleeve will be less than 9 inches from the open end of the lead sleeve, as shown in Fig. 45. In doing this work care must be taken to remove all pieces of paper, jute, tape or other material which might obstruct the flow of the compound which is to be poured in after the lead sleeve is in *place.*

The wires shall be tightly wound, close to the end *the lead cable sheath,* with a number of layers of wic

Fig. 45. Pothead.

in such a manner as to prevent the compound from entering the cable.

If rubber cable is used, the wrapping about the rubber cable shall be removed to such a distance that only about 1½ inches of wrapped cable shall enter the compound when the sleeve is drawn up into position for wiping. If a number of small rubber cables are used in place of a large cable, the wrapped part of the rubber cables within the sleeve shall be bound together with friction tape.

If loose wires are used they shall be temporarily bound together at a distance of a few inches above the sleeve in such a manner that the wires entering the sleeve will be fairly close together but will be loose enough for the compound to flow thoroughly between them. After the sleeve is filled the wires shall be permanently bound together immediately above the compound.

The splice proper shall be bound with several turns of twine in order to reduce it to a diameter which will allow the lead sleeve to be drawn on without disturbing the sleeves

covering the spliced wires. The turns of twine shall not extend beyond the last of the wire joints at the pothead wire end of the splice.

When the sleeve is put in place care shall be taken to center the cable sheath within it. The sleeve shall be allowed to project over the lead cable sheath 1½ inches and be connected to it with a wiped joint. After this joint has cooled sufficiently to be secured from injury by handling, the cable and sleeve shall be fastened in an upright position, the sleeve warmed until it becomes barely possible to touch it with the hand, the wires centered in the sleeve and the sealing compound poured in slowly and carefully. Before pouring begins the compound shall be brought to a temperature such that it will flow freely, but shall not be hot enough to injure the insulation of rubber covered wire when immersed in it for one minute.

To facilitate the pouring of the sealing compound it should be heated in a gallon coffee pot and poured therefrom until the sleeve is filled.

After the terminal has become thoroughly cold, the open end of the sleeve shall be dressed down just enough to give the terminal a finished appearance. The top of the sleeve shall be left open so that additional compound may be added as the compound settles. Potheads should be frequently inspected during the first six months and sealing compound added when necessary. No pothead shall be mounted in other than an upright position if exposed to the weather. When it is necessary, in inside construction, to place the pothead in a horizontal position, the open end of the lead sleeve shall be wrapped with tape to prevent the compound from running out and care shall be taken to locate the pothead where it will not be exposed to excessive heat.

Suggestions in Regard to Potheads:—In branching a small lead covered cable from a pothead splice it should be taken out at the base of the lead sleeve making a double *wiped joint, rather* than run out parallel with the rubber *covered wires* or cable.

Should occasion arise when it becomes necessary to shorten the length of the lead sleeve, a sleeve of greater diameter than is ordinarily recommended may be used but the space between the last wire joint on the rubber covered wire end and the open end of the sleeve shall always be at least 9 inches, as this is the space where the efficiency of the seal is maintained.

Patent Cable Splicing Joints:—In order to obviate the expense incident to the employment of experienced labor for the making of the plumber's joint required at each end of a cable splice, and because it is not always possible to have at hand workmen capable of producing such work, as is the case with exchanges having a limited amount of cable, many attempts have been made to produce some form of cable joint which could be applied by a man conversant with the ordinary details of line work, and which in sealing efficiency, initial and maintenance costs, would compare favorably with the lead sleeve joint. A very satisfactory form of cable splicing joint is shown in Fig. 46, known as the Bierce Cable

Fig. 46. Bierce Cable Sleeve.

Sleeve, and manufactured by the Specialty Device Company. The joint consists of a close grained iron sleeve equipped with a rubber cone at each end which fits tightly to the cable sheath, and is compressed between a head on the iron sleeve and another by four machine bolts. A high grade of rubber is used in the manufacture of the cones, and as they are hermetically sealed from light, air and moisture, there *should be no deterioration.* The labor of installing this *sleeve consists only of* tightening the eight bolts in the two *leeve heads, and as the* operation involves no solder, can

be performed expeditely and by a person of little experience. It is obvious that this joint can be easily opened for repair purposes.

Another type of cable splicing joint is that manufactured by W. N. Mathews & Brother. The parts shown in Fig. 47

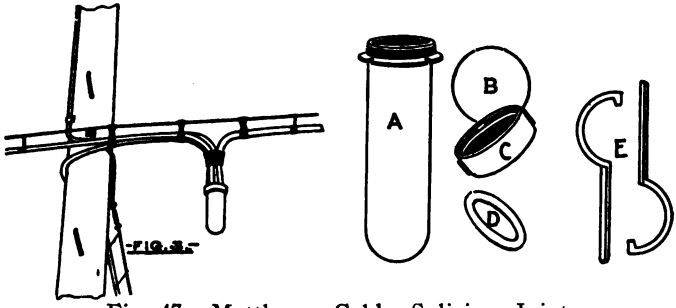


Fig. 47. Matthews Cable Splicing Joint.

are as follows: A-closed lead sleeve with externally threaded brass collar, B-lead gasket, C-internally threaded brass collar to fit over A, D-rubber washer, E-spanner wrench for closing joint. In making this joint the two cables are bent at right angles in a gradual curve, and their ends brought through two holes bored in the lead gasket. The brass collar is then put on with the flange up and the threaded part down, and molten solder poured into the cup formed by the lead gasket and the brass collar. The lead sheaths of the cables where they project through the gasket are then removed and the wire spliced. The rubber ring is now placed inside of the internally threaded brass collar and the lead sleeve screwed tightly in place by means of the spanner wrenches. The completed joint is moisture proof and changes or repairs may be made in the cables at any time without any labor in the opening of the joint other than the unscrewing of the lead sleeves. The sketch to the right of Fig. 47, designated as Fig. 3, shows this joint in position on a cable.

It should be noted that the opening of either the Bier*s* *or the Matthews* joint involves no extra material for

sleeve, and because of their simplicity, these joints should be of especial service to the small company.

Supporting Splices:—Lead sleeve splices over 20 inches long should be fastened to the messenger wire with a loose tie of marlin at the middle of the splice and 2 cable hangers at each end in order to prevent the splice from being strained. Fig. 39.

The method of supporting cables at branch splices is shown in Fig. 48. All cable splicers should be provided

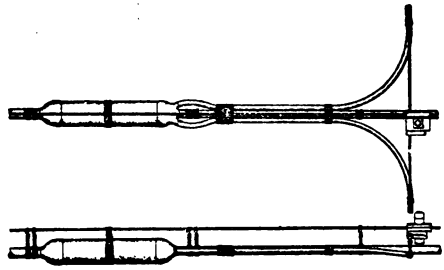


Fig. 48. Method of Supporting Cables at Branch Splices.

with stencil numbers and an individual symbol, which is on record in the construction department office, and each splicer should be required to stamp his symbol and the date on the wiped joint of every lead sleeve, splice, pothead and bond that he completes. Fig. 42.

Mechanical Protection:—Where primary circuits are above and within 3 feet of a guy, aerial cable, or messenger, the guy, cable, or messenger should be protected by rubber hose laced with marlin at intervals of 4 inches along its length. The hose should extend a distance of 5 feet on each side of the primary circuit. The cable hangers should remain in position on the cable. Figs. 49 and 50.

It is not considered necessary to place hose when a primary circuit is below the cable or messenger except where the distance is less than 3 feet or where there is a liability of a swinging cross, nor do guys, cables and messengers require protection from secondary circuits.

Fig. 49.

Fig. 50.

Fig. 51.

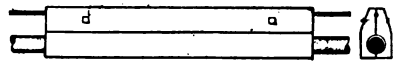


Fig. 49. Method of Protecting Cables with Rubber Hose.
Fig. 50. Method of Protecting Guys and Messengers with Rubber Hose.
Fig. 51. Method of Protecting Cables with Wood Shield.

Where guys, cables or messengers cross over a trolley and are within 10 feet of the same, they should be protected with hose as shown in Figs. 49 and 50. The hose should extend a distance of 5 feet on each side of the trolley on straight track, and at curves and other exceptional places the hose should extend as much more than 5 feet as may be necessary.

Where the cable is liable to injury from chafing against trees or other objects an aerial cable shield should be placed as shown in Fig. 51. In this case the cable hangers should be taken off where the shield covers the cable. This particular shield consists of wood moulding fastened with ¼ by 3¼ inch machine bolts, the moulding being cut to the necessary length. Other forms of shield may consist of wood strips lashed around the cable, or a shield may be made of No. 22 B. W. G. galvanized sheet iron, formed around the messenger wire and cable.

Bonding and Grounding:—At the office pole, all terminal poles, and at intervals of 1,000 feet along the cable, the cable and messenger should be bonded together with a twisted strand of tinned, soft copper wire. The connection to the cable is best made by means of an "Adams" bonding clamp, and to the messenger wire by means of a standard guy clamp. *Fig. 52.*

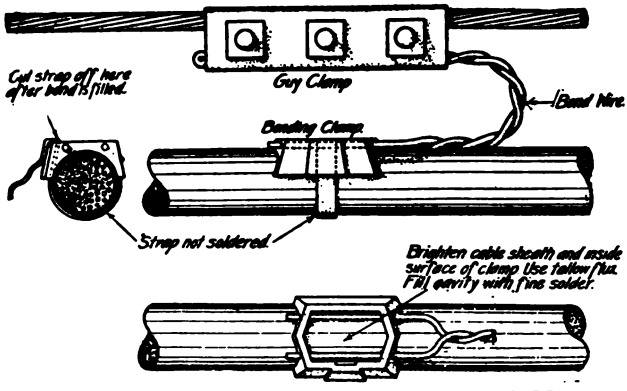

Cut strap off here after bond is filled.
Guy Clamp
Bond Wire
Bonding Clamp
Strap not soldered
Brighten cable sheath and inside surface of clamp. Use tallow flux. Fill cavity with fine solder.

Fig. 52. Method of Bonding Aerial Cable and Messenger.

At the office pole a double ground connection for the bonded cables and messenger should be made, and at all terminal poles, ends of cables, and every fifth bond along the cable a single ground should be installed. The ground wire may consist of a length of ⅜ inch steel strand clamped to one of the messenger wires and securely fastened to the pole by means of staples driven every two feet. The end of the ground wire is carried through a ground pipe, and buried in the ground to a depth of six feet at the base of the pole, and imbedded in about 3 bushels of coke. The ground pipe should extend well into the coke, and the ground wire should be carefully wiped to the iron pipe at both ends so as to completely exclude moisture. Fig. 53.

Protection of Cable from Abnormal Currents:—The protection of an aerial cable from abnormal currents which may be carried by open wire lines connected to it is accomplished by placing fuses, or fuses and carbons, between the tapping point on the cable and the open wire line. Approved practice has limited such protection to the use of 5 ampere fuses between aerial cables or other wires and underground cables, and the use of fuses and carbons where open wire lines of *over one-half mile in* length enter aerial cables. On account *of their short length* and because rubber insulated wire is

used to a great extent for subscriber drops, and also in the case of substations served by block or building wiring connected directly to either an aerial or underground cable terminal, no fuses or carbons are required at the tapping terminal on the cable.

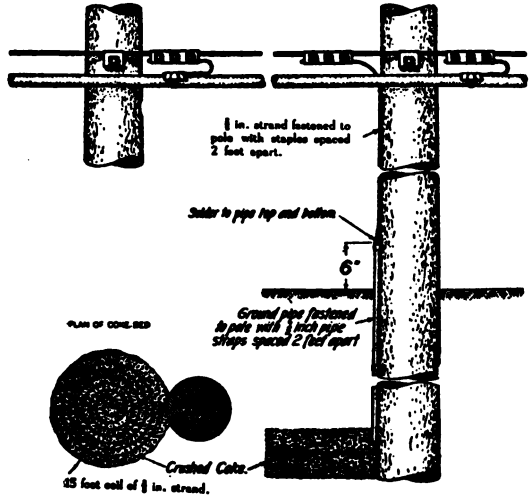


Fig. 53. Method of Grounding Aerial Cables.

Complete protection is afforded by the provision of a standard cable box equipped with fuses at the junction of the aerial and underground cables; a cable box equipped with fuses at the ends of all aerial and underground cables, with provision of lightning arrestors for all open wire lines of over one-half mile in length; and the employment of unprotected terminals for the distribution of subscribers' lines at intermediate points along the cable, (with additional equipment of fuses and carbons for all open wire lines entering the terminal).

Cable Boxes:—Cable boxes present the most convenie*and economical* means for the mounting and housing of te

and carbons. They are arranged to accommodate 25, 50, 100, 150 and 200 pairs of conductors, and should be so designed that the fuses and carbons can be installed individually, and only as required. The dry core cable is terminated in cable boxes by means of potheads.

Cable boxes should be substantially made of 1¼ inch thoroughly seasoned, first quality, white pine lumber well jointed. The front of the box should be closed by twin doors which rest against a rubber gasket extending along the open side. The outside of the box should be protected with two coats of weatherproof paint and the inside with two coats of fireproof paint. For convenience in keeping a record of the cable conductors, the inside of the cover of the box should be stenciled with a form for this purpose.

Cable Terminals:—Cable terminals which necessitate the making of a pothead on the connecting cable are expensive to install and maintain. For this reason terminals which make use of this method are not described.

A good terminal should be reasonably low in first cost and easily installed and maintained; it should have a life as great as that of other portions of the cable plant, high insulation under all conditions during its life, should form a hermetical seal for the cable, and be neat and inconspicuous in appearance.

Western Electric Type 14 Terminal:—The terminal designed by Messrs. S. P. Grace and R. A. L. Snyder of the Central District and Printing Telegraph Company at Pittsburg, has all the desirable features of a good terminal, and is well adapted for block wiring. This terminal consists of a cast iron box divided into a closed compartment and an open one by a porcelain plate in which binding posts are fixed. A hinged cover closes the open compartment. Lead covered dry core cable is led into the closed compartment at the bottom through a piece of brass tubing and the conductors are soldered to the inner end of the binding posts, after which the closed compartment is nearly filled with cable compound. Drop wires are secured to the outer ends of the binding posts and fan out through small holes in the

back of the box which are plugged with putty and is removed only as it becomes necessary to pass wires through. The hinged cover is flanged at the top and sides to prevent the entrance of water, the top of the box and cover being given a considerable pitch to insure its satisfactory shedding, and the lower end of the cover extends a half inch below the bottom of the box to prevent water from working up from the edge of the cover into the box. The box and cover are japanned, and the inside of the cover is enameled white and a form stenciled for the marking of pairs, which is to be done with a soft pencil. This terminal is usually assembled with six or eight feet of dry core cable. Made in 10, 11, 15 and 26 pair sizes.

Fig. 54. Cook Type M-4 Terminal.

Cook Type M-4 Terminal:—The terminal illustrated in *Fig. 54,* loaned by Mr. Frank B. Cook, is composed of tw *porcelain* plates mounted on a strong steel base, and fi

with a galvanized iron or copper cover. A gasket separates the two porcelain plates, which are held together by four brass bolts and to the bracket base by two galvanized iron bolts. The dry core cable is brought in through a supporting nozzle at the base and the wires fan out through hollow screws and are soldered to the outside of these screws, which form binding posts with lock nuts for the reception of drop wires. The box is then filled with cable compound, which effectually seals the end of the cable against moisture. This terminal is made in sizes from 5 to 50 pairs.

Fig. 55. Sterling No. 344 Terminal.

Sterling No. 344 Terminal:—The terminal shown in Fig. 55, loaned by the Lafayette Electric Company, consists of a bracket, base, front and back in one casting, to which *are bolted hard maple* strips assembled and joined into a *moisture proof box,* which is to be filled with compound. *The maple sides of this* box carry brass connecting studs,

the cable end being fitted with soldering clips, and the other end with lock nuts for the drop wires. In the terminal base is screwed a brass nipple for the reception of the dry core cable. This terminal is made in sizes from 5 to 25 pairs.

Protected Terminals:—As the occasion may often arise in which it is desired to provide a terminal with partial or full equipment of fuses and carbons, the following standard types of protected terminals are described.

Cook Type S-16 Terminal:—This terminal, illustrated in Fig. 56, is of all steel construction, and furnished without

Fig. 56. Cook Type S-16 Terminal.

protection but with connecting posts only, enabling the complete installation of the cable with the terminal. Connecting posts are in the shape of hollow studs, through which cable wires are brought to the outside of the terminal be and soldered. The protectors designed for use with

terminal are in units, Fig. 57, and attach to the connecting studs by means of split spring german silver contacts, this being a continuation of the line or cable fuse clips, and neither bolts, screws or nuts being required to secure them to the terminal box. This terminal is equipped with a Cook self-soldering nozzle and is made in sizes from 10 to 50 pairs.

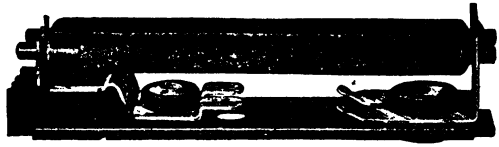


Fig. 57. Cook Type H-29 Protector Unit.

Fig. 58. Sterling No. 270 Terminal.

***Sterling No. 270* Terminal:**—Fig. 58 illustrates a protected terminal manufactured by the Lafayette Electric Company. Its protection equipment is a tubular fuse and carbon mounted on continuous hard maple strips, which form

the sides of a closed compartment. This compartment is built on a heavy iron base casting and its end and top are completely removable wood panels. In connecting the cable into the terminal the top and end panels are removed, giving easy access to the terminal posts within. After the connections are made, the end panels are replaced, a small amount of compound poured in and the top fastened in position. This terminal may be readily opened for inspection at any time. Made in sizes from 10 to 50 pairs.

Fig. 59. Bissell Terminal.

Bissell Terminal:—The terminal shown in Fig. 59, is manufactured by the F. Bissell Company, and employs a pencil fuse and carbon arrestors. Contacts are heavy machine screws with hexagon nuts for both cable and drop wires. Sizes 5 and 10 pairs.

Hall Terminals:—The terminal illustrated in Fig. 60, designed by Mr. Frank B. Hall, has been on the market for some time, the mica fuse equipment which it employs being in favor with many. It is made with a cast iron base, and in the later models with an ebony asbestos mounting plate equipped with screw lugs for the attachment of drop wi

Fig. 60.

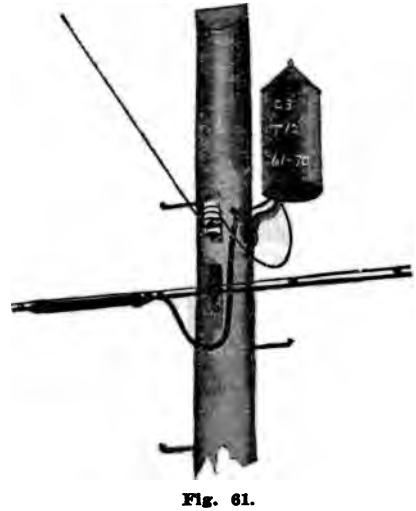


Fig. 61.

Fig. 60. Hall Terminal.
Fig. 61. Distributing Pole with Hall Terminal.

Fig. 61 shows a 10 pair terminal in place on the pole and the method of taking off subscribers' drops. The terminal is made in sizes from 10 to 50 pairs.

Hall terminals are connected to the dry core cable by means of six foot lengths of lead covered rubber cable. The end connected to the terminal has the lead sheath removed a sufficient distance to provide wire length sufficient to reach the terminal clips; the wires are then turned back over the sheath and the cable immersed in a pot of hot compound. The cable should remain in the compound long enough for the compound to penetrate and seal the cable, but not long enough to injure the insulation. The conductors are then laced up, fanned out, and soldered to the clips. The lead sheath is to be turned back so as to form a collar on the *inside of the terminal* base, thus supporting the cable when *the terminal is in place.*

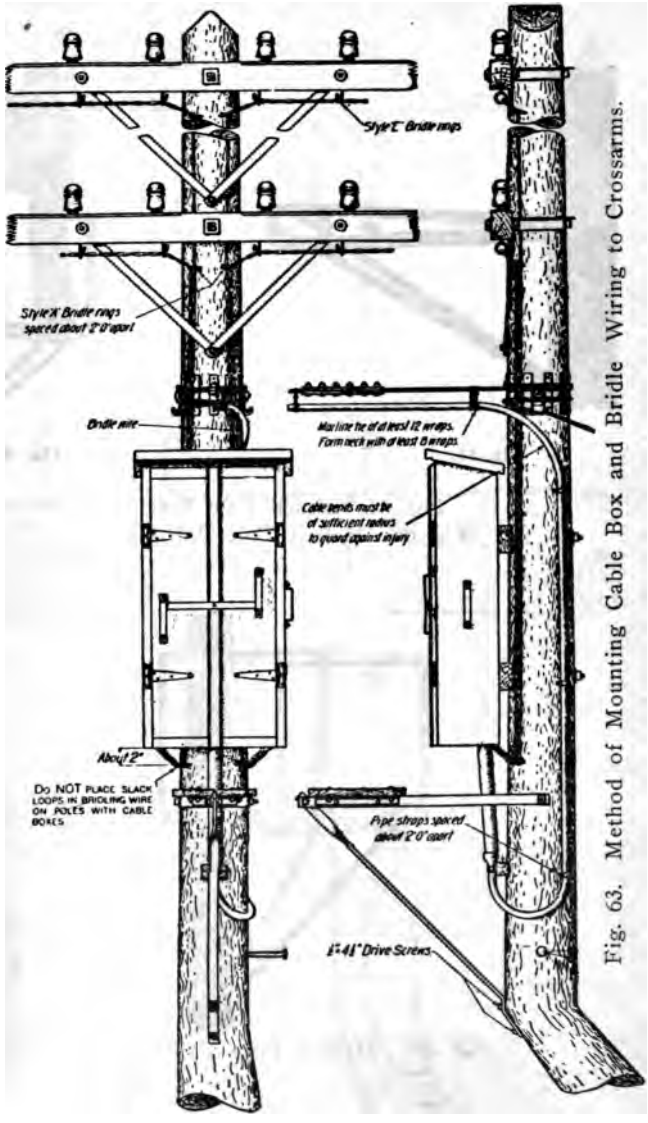

Style 'C' Bridle rings
Style 'X' Bridle rings spaced about 2'0" apart
Bridle wire
Make last tie of at least 12 wraps. Form neck with at least 8 wraps
Cable bends must be of sufficient radius to guard against injury
About 2"
DO NOT PLACE SLACK LOOPS IN BRIDLING WIRE ON POLES WITH CABLE BOXES
Pipe straps spaced about 2'0" apart
1"-4½" Drive Screws

Fig. 63. Method of Mounting Cable Box and Bridle Wiring to Crossarms.

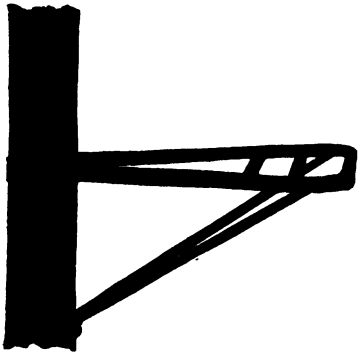


Fig. 64.

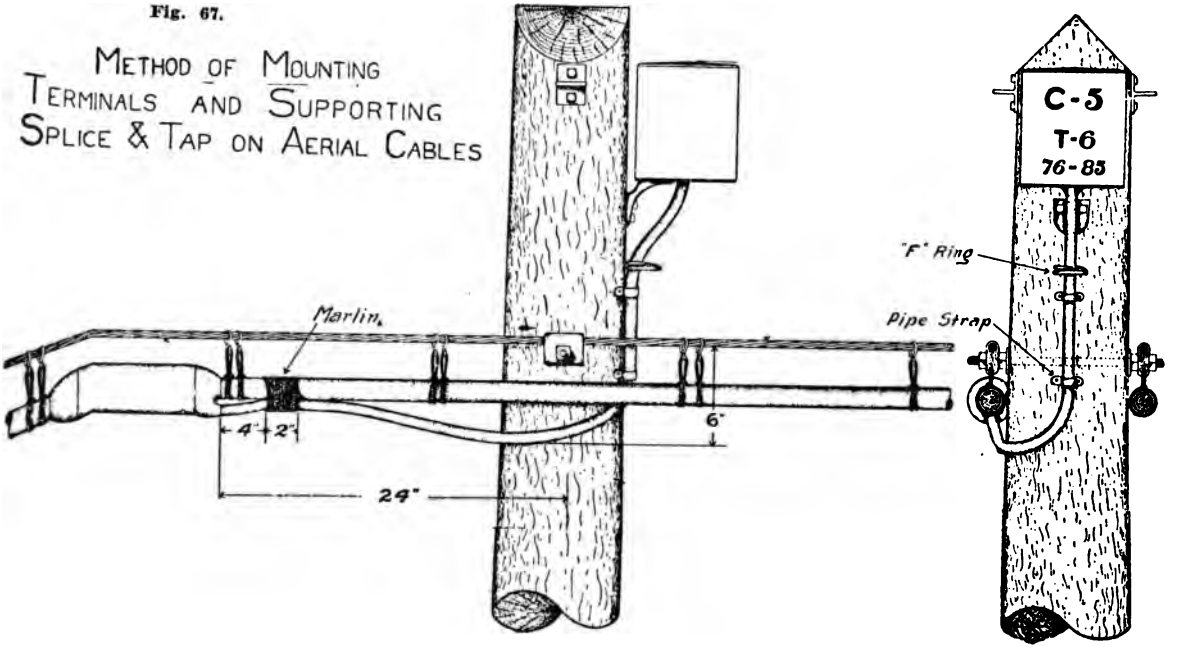
Fig. 65.

Fig. 64. Bissell Pole Seat.
Fig. 65. Hallett Pole Balcony.

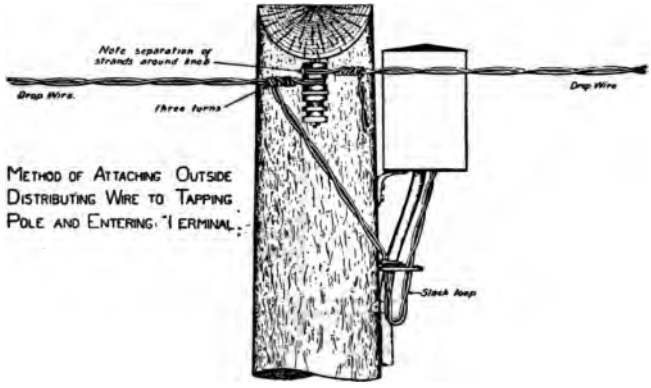
Fig. 66. Hallett Pole Balcony.

Fig. 67.

METHOD OF MOUNTING TERMINALS AND SUPPORTING SPLICE & TAP ON AERIAL CABLES



Attachment of Cable Boxes:—Cable boxes should be placed below the cable and on the side of the pole next to the office except at underground terminal poles, where they should be placed on the opposite side. Cable boxes of 100 pair and less should have a pole seat mounted as shown in Fig. 63. Cable boxes of 150 pairs and larger should have



METHOD OF ATTACHING OUTSIDE DISTRIBUTING WIRE TO TAPPING POLE AND ENTERING TERMINAL

Fig. 68.

a pole balcony mounted in a similar manner. Fig. 64, loaned by the F. Bissell Company, illustrates a good type of pole seat. Figs. 65 and 66 are standard type of pole balconies, manufactured by the Hallett Iron Works.

Fig. 63 also shows the method of bridle wiring between cable boxes and crossarms.

Attachment of Cable Terminals:—Terminals used for distribution along the lead are mounted on the side of the pole away from the office. The method of attachment to the pole and the scheme of wiring to be followed at terminal poles is shown in Figs. 67 and 68.

Termination of Cable at Offices:—All cables should be terminated directly on the main distributing frame with wool butts not less than 8 feet, and not more than 50 feet in length.

Aerial cables may be brought into the central office by *means of a cable rack* as in Fig. 69, or by means of under-*ground pipes as in Fig. 70.*

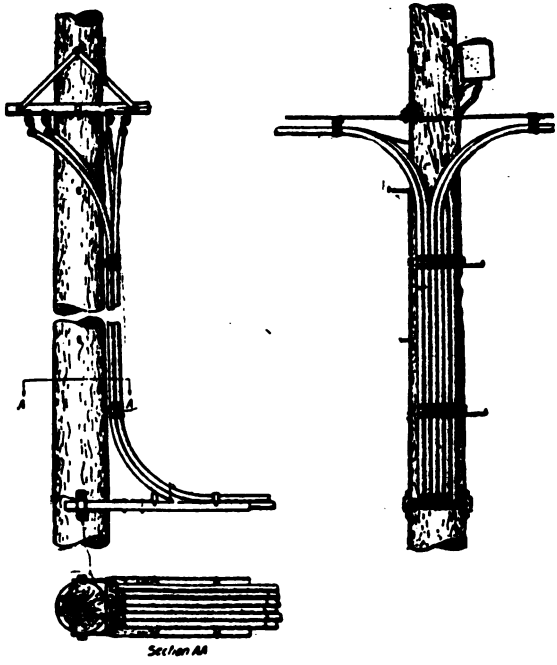
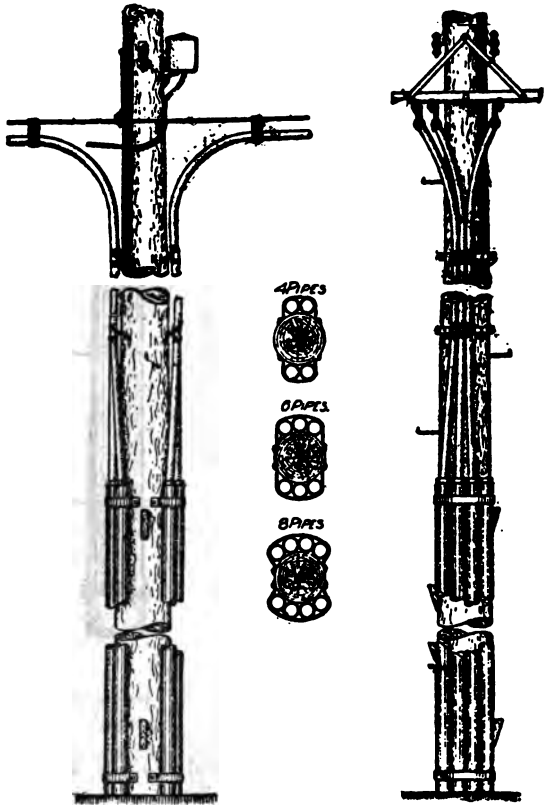


Fig. 69. Method of Bringing Aerial Cables into Centra Office by Means of Cable Rack.



g. 70. Method of Bringing Aerial Cables into Central Office by Means of Underground Pipes.

Fig. 70.

UNDERGROUND CABLE WORK.

Drawing-in Cables:—The cable should not be started into the duct until it is clean and free from obstructions. While the cable is being drawn in it should be protected by a lead collar arranged so as to prevent the edge of the duct from injuring the cable sheath.

The reel holding the cable should be mounted on an axle of such a height as will cause it to clear the street about 6 inches, so that it may easily and freely revolve.

The reel should be placed on that side of the manhole at which the cable enters the duct so that the cable can enter the manhole from the top of the reel; this gives a simple curve from the reel to the duct without danger of abrasion, sharp bends or kinks. If the cable or any conductor in it is provided with indentifying marks, all sections should be laid in the same direction to insure proper registration.

Cable Grips:—Cable grips may be purchased ready for use as in Fig. 71, or may be made by cutting 6 or 8 foot lengths of No. 12 B. W. G. steel wire (using the rodding wire if it is in suitable condition), bunching four, six or eight of these wires together, (depending on the severity of the pull) and wrapping them in two halves spirally around the cable sheath in opposite directions, twisting the ends securely together.

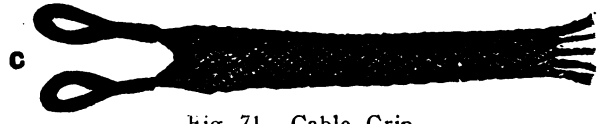


Fig. 71. Cable Grip.

Draw Rope:—A manilla rope of best quality and from ¾ to 1½ inches in diameter should be used for drawing in the cable. The ends should be provided with an "eye" around a steel thimble fastened to a short length of chain with a swivel at the end, and terminated with a pair of sister-hooks. *These should* be inserted in the loop of the wire grip on th *cable and* prevented from opening by several wraps of w

Skids:—A skid should be used in connection with all methods of pulling hereinafter described. This skid is provided with holes every 4 inches along its entire length, through which steel pins secured by cotter pins may be placed, thus providing movable shafts for the pulleys.

The lower pulley should be placed opposite the duct, and the rope leaving the duct be passed under this pulley, up to and over the upper pulley just above the street surface. The bottom of the skid should rest against the wall of the manhole and the top against an iron rod placed under the manhole frame.

Drawing Apparatus:—If the cable is light and short, it should be pulled by hand.

On heavy cables where the installation is not large and the streets not congested with traffic, a heavy team of steady horses should be used by rigging the drawrope through snatch blocks in such a manner that the horses when pulling move about four times the distance that the cable is moved.

In places where horses cannot be employed, a ship's capstan mounted on a frame which can be fastened to the pavement may be used.

On large installations a six horse power gasoline hoisting engine mounted on a truck should be employed. The drawing-rope is passed several times around the capstan head on the axle of the drum of the hoist, the speed being regulated by the pressure applied to the capstan head with the draw-rope and the rope being drawn back hand over hand as the cable is drawn in. A steel hoisting rope is used with this apparatus.

A little flake graphite mixed with water and applied to the cable as it is drawn into the duct makes the cable pull much easier.

Supporting Cables:—In order to avoid damage to the *cables by abrasion from* the edges of ducts or by careless *workmen, they should* be systematically arranged on the *manhole walls and held in* place by some form of cable sup-

Fig. 72. Underground Cable Support.

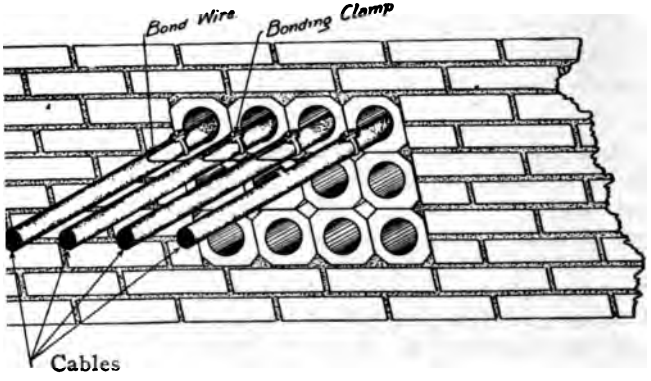


Fig. 73. Method of Bonding Underground Cables.

port, a good type of which is shown in Fig. 72, lo
the Standard Underground Cable Company. This
can be easily installed or removed, and being of sectic
struction, can be extended to accommodate additiona

Bonding of Cables:—In general, all cables sh
bonded together at frequent intervals, usually at n
1,000 feet apart and wherever there exists a diffe
potential of .2 volts. This reduces the resistance
sheaths of the cables and prevents the passage of
from one cable to another by other than a metallic
tion, with consequent electrolysis. The method of
cables is shown in Fig. 73.

CHAPTER IV.

CABLE RECORDS.

An important factor in the matter of securing the best possible use of the cable distributing plant is an effective system of cable records. These records are intended to assist the wire chief in the assignment of cable conductors, in handling trouble, and otherwise keeping record of the use that is being made of the plant. Such a system of cable records should consist of maps showing the cable layout of the exchange, a book in which is kept a record of the occupancy of each cable, and a card index by line numbers acting as a cross reference to the book.

Cable Maps:—The plant maps should be drawn to a scale of not less than two hundred feet to the inch. Aerial records should show all important streets, house numbers, section lengths measured between pole centers, all terminals, cable boxes and cables properly located and the number of pairs in the cable and the conductor gauges. The pair numbers of the various terminals are written at right angles to the pole on which the terminal is placed. Fig. 74 shows a typical cable map.

Maps for small exchanges may consist of a single sheet, but in the case of larger exchanges, the map should be divided into sections that can be easily handled, and in offices having many underground cables an individual map of each underground cable should be provided. This individual map is similar to that for aerial cables, except that the scale should be one hundred feet to the inch, and the position of the cable in the duct line is given. In counting ducts, stand with the back to the telephone office, thus bringing No. 1 duct in the upper left hand corner.

Cable Records:—This book should be in loose leaf form, *and have sheets* of such quality as will readily permit of *pencil erasures.* Fig. 75 shows a typical record of this kin

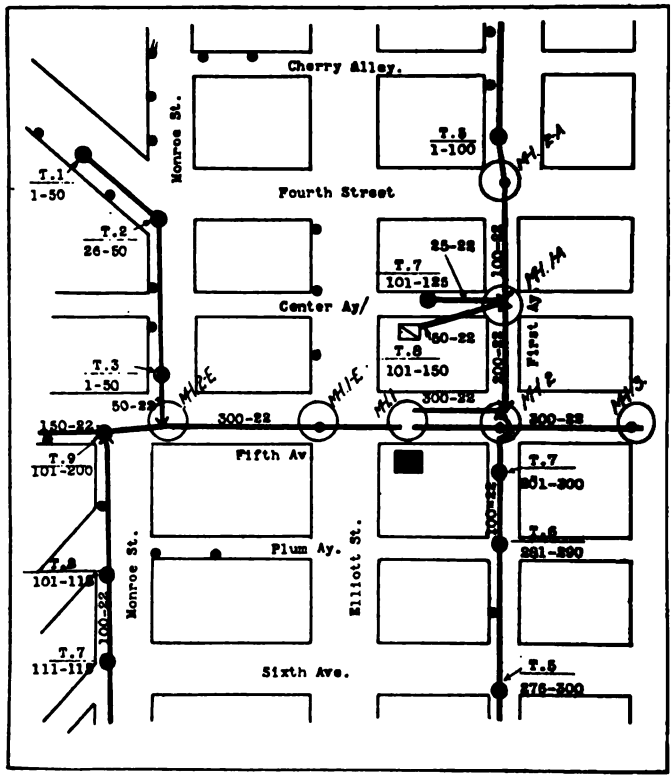


Fig. 74. Specimen Plant Map.

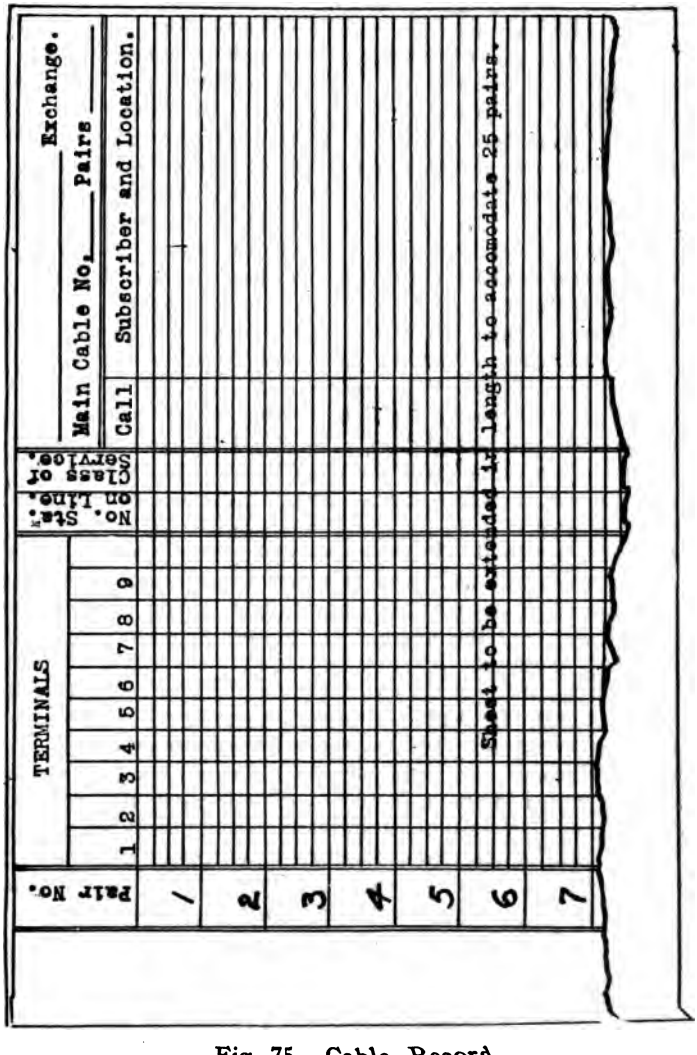


Fig. 75. Cable Record.

Each page is arranged to accommodate 25 cable pairs, hence there will be as many pages for a cable as there are twenty-five pair divisions of the cable. The pair or conductor numbers are placed at the left hand side of the sheet. A separate column is provided for each terminal headed by the number of the terminal. The street location of the terminal may be shown on this sheet by extending the terminal column one or two inches at the top and writing the street location in this space, but where proper cable maps are provided, this is not necessary. A red line drawn vertically in the column under the terminal number, and extending opposite the numbers of all pairs which appear at the terminal indicates the pairs which are tapped out. The presence of an arrow indicates that the pair combination is carried over to the next sheet. Whenever a cable pair is used, it is indicated by a pencil check mark placed on this line under the proper terminal number. The total number of pairs in use at any terminal will therefore be the sum total of the pencil check marks on the red line under that terminal number. Whenever possible, party lines should be made up in the same terminal. The same conductors checked on more than one red line will show that this is not being done. To the right of the terminal column are four columns to be used as follows: (1) the number of stations allowed on a line, (2) class of service (whether business or residence), (3) call number, and (4) the subscriber's name and address. It will be noted that the record is ruled with four horizontal lines running across the sheet to the cable pair number; this is for the purpose of accommodating the names and addresses of subscribers in the case of two or four party line service. The number of stations allowed on each line is placed in an individual column in order that the extent to which party lines are filled may be made as clear as possible and the figures in this column in connection with the record of occupation in the subscribers' column, show at a glance the extent to which the party lines are filled. The call number is of course the line or directory number of the subscriber. *This information should* be placed on the record with a soft *pencil.*

Card Index:—This card, shown in Fig. 76, bears supplementary information as to the jack and panel number of the subscriber and details of equipment and service contract. It may be of any suitable size, three by five inches, or four by six inches being conveniently handled. It should be filled out as indicated, the reverse side being used as a trouble record if desired.

Telephone Number

Name

Location

Cable No. Pair No. Tap No. Lamp Jack No.

Style of Phone Date in

Instrument No. Transmitter No.

Extension Style Transmitter No. Date

Extension Bell

Special Equipment

Fig. 76. Cable Record Card Index.

Party Line Combinations:—In forming combinations for party line service, an attempt should be made to completely fill the combinations from the same terminal or at least within the same square. To have a number of incompletely filled party lines is not only extravagant practice as regards the cable plant, but the substations served by them receive service of a better grade than that to which they are entitled by their rates.

Cable Plant Efficiency:—In every cable plant, a portion of the cable conductors is necessarily idle. This proportion of spare conductors has been found to be greatly variant with local conditions, in some cases being 50 per cent. or greater. It is important to reduce this proportion of idle conductors as much as possible in order to realize the greatest value from the cable plant.

While such a system of cable records as has been described has its first use as a guide to the wire chief in the proper assignment of cable conductors, it may be made of value in studying the use that is being made of the plant, the efficiency of the party line grouping, the adequacy of the multiple distribution, in passing upon questions relating to the need for additional main and branch cable facilities, and as a guide to the contract department in obtaining contracts for service which can be supplied without additional investment in plant construction.

Considering the uneconomical conditions which may readily creep into existence if party line assignments are not made to the best advantage, the small amount of time required for a study of this kind from records similar to those described is undoubtedly a good investment. This data may be compiled at stated intervals, making the preparation of it on suitable blanks a part of the wire chief's routine work, or it may be compiled whenever plant conditions seem below normal, or for the purpose of passing upon questions of plant extension.

The method of preparing a report of the latter character is as follows: Take cable maps of the exchange district and opposite each terminal and cable box, mark by line numbers all stations working from the terminal. Indicate the efficiency of the party line grouping by a fraction placed opposite the line number. To illustrate, 2/4 opposite a line number means that this is a four party line with two stations upon it. This information should be obtained from the wire chief's cable book, and checked by the card index and inspection of the plant. Then place the terminal numbers in a column, and opposite each terminal number mark in columns the total number of lines, stations, and vacant party line positions in that terminal. A summary of this data will give some idea of the percentage of pairs in use, the relative terminal facilities available, and the party line grouping, but for information of a more definite character concerning the details of the plant, the following additional data should be obtained:

Report on condition of Cables in Chestnut Exchange, with reference to per cent. of pairs and copper mileage in use, efficiency of distribution and party line grouping, and amount of copper used per pair and per station. December 15th, 1909:

Chestnut Exchange Cable No. 1:

336 feet 100 pair cable..... 33,600 pair feet
6,911 feet 50 pair cable..... 345,550 pair feet

Total pair feet in cable..... 379,150

Terminal	Stations	Lines	Vacant Positions	Dist. from Office Ft.	Pair Feet
Branch of Cable: Pairs 1-50.					
1-D	3	3	0	429	1,287
2-D	6	6	6/4	537	3,222
6-D	6	4	4/4	942	3,768
8-D	2	2	6/4	1,133	2,266
9-D	4	2	1/4	1,236	2,472
12-D	36	15	6/4 & 1/2	1,530	22,950
Branch of Cable. Pairs 51-100.					
14-H	17	17	0	6,053	102,901
17-H	1	1	0	5,742	5,742
22-H	4	2	1/4	5,182	10,364
39-H	14	6	4/4	3,621	21,726
59-H	1	1	3/4	1,211	1,211
62-H	1	1	0	762	762
64-H	4	3	0	471	1,483
Totals,	99	63	....	.....	180,084

Total wire mileage..... 379,150 pair feet
Total wire mileage in use..... 180,084 pair feet
Per cent. of wire mileage actually in use..... 47.3
Total number of pairs in cable..... 100
Total number of pairs actually in use..... 63
Per cent. of pairs actually in use..... 63
Per cent. of copper of working pairs in use 762

Wire mileage per station	.345 miles
Wire mileage per line	.541 miles
Dead wire mileage per station	.108 miles
Dead wire mileage per line	.173 miles

The average of the entire plant is found by treating each cable in this manner, and making a summary of the different values obtained. The following explanations and definitions may be of service in making these studies:

Total Wire Mileage:—The total length of pair feet in a cable. It is found by multiplying the length of the cable by the number of pairs contained in it. The cable in the above study contains 379,150 pair feet, of which 33,600 pair feet is in a 100 pair cable, and 345,550 pair feet in 50 pair cable.

Cable and Terminal Numbers:—The numbers by which the cable and terminal are known and as given in the cable book and on plant maps. Under the heading "Terminal" in the first column are placed the terminal numbers. The letter affixed to the number indicates the street location of the cable lead carrying this terminal, and a change in this letter, as well as in the pair numbers given, shows that the terminals are not all on the same branch of the cable.

Stations:—Under this head is placed the total number of stations served from the terminal. The total of this column gives the total number of stations working in this cable.

Lines:—Under this head is placed the total number of lines in use at the terminal. The total of this column gives the total number of lines or pairs in use in the cable.

Vacant Positions:—The figures in this column indicate the efficiency of the party line combinations or grouping. The denominator of the fraction expresses the class of service; 4 meaning four party, 2 indicating two party line combinations. The numerator indicates the number of party line stations of the class designated by the denominator *which are required* to reduce the figure to zero, or the number *of party line* stations of the class designated by the denominator which could be served from the terminal without

the use of additional cable pairs. In the example given, 6/4 on the second line in this column indicates that 6 four-party sub-stations can be served from this terminal without the use of additional cable pairs. If the numerator of this fraction should be considerably larger than the denominator, it will, in general, be advantageous to re-arrange the party line combinations, which will leave several more pairs available for future use in the terminal.

Distance from Office:—The figures in this column represent the respective distance of the terminals from the central office, expressed in feet. Scaled distances from the plant map will be accurate enough for the purpose of this study.

Pair Feet:—This is the distance in feet of the terminal from the exchange multiplied by the number of lines in use at that terminal. The total of this column represents the amount of total wire mileage in use in the cable and is compared with the amount of total wire mileage to find the per cent. of pair mileage in use.

Per Cent. of Pairs in Use:—The ratio of the number of total pairs used to the number of total pairs in the cable. It is found by dividing the number of total pairs actually in use by the number of total pairs in the cable.

Per Cent. of Pair Mileage in Use:—The ratio of the amount of total wire used for subscriber purposes to the amount of total wire in the cable. It is found by dividing the total amount of live and dead wire used for subscribers by the total amount of wire in the cable.

Per Cent. of Copper of Working Pairs in Use:—The ratio of the amount of copper actually used for subscriber purposes to the total amount of copper used for this purpose. It is found by dividing the amount of total mileage from the subscriber to the exchange by the amount of total mileage from the end of the pairs used to the exchange. It is to be noted that this shows the efficiency of the pairs used *without* reference to the number of pairs used in the cable *and* whether the cable has the proper taper.

Wire Mileage per Station:—Total wire mileage (live and dead) used for each station. It is found by dividing the amount of total wire mileage used for any cable by the total number of subscriber stations on that cable. The actual amount of wire used is live wire.

Wire Mileage per Line:—Total wire mileage (live and dead) used for each line. It is found by dividing the amount of total wire used in any cable by the number of lines in use in that cable.

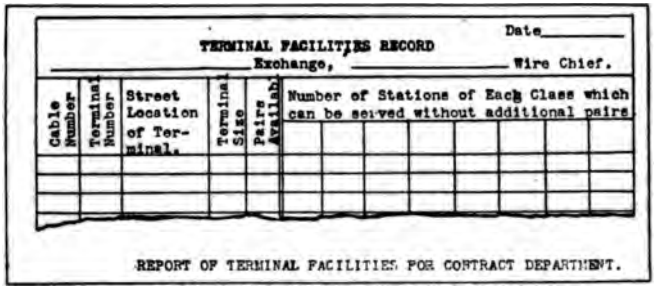
Live Wire, or Wire Actually in Use:—The wire actually used from the farthest subscriber on any pair to the exchange.

Dead Wire:—That which cannot be used for subscriber purposes. It is the wire from the farthest subscriber on any cable pair to the outer end of the cable.

Dead Wire Mileage per Station:—It is found by dividing the amount of dead wire mileage in any cable by the number of subscriber stations on that cable.

Dead Wire Mileage per Line:—It is found by dividing the amount of dead wire mileage in any cable by the number of lines working in that cable.

Solicitor's Work:—To properly present the information contained in the study in working form for the solicitor, a form should be prepared which will show the cable number, the number of the terminal and its street location, the size of the terminal, the number of pairs appearing at the terminal that are unoccupied in that or any other terminal, and the number of party line stations of each class that can be connected to the terminal without using unoccupied cable pairs. Fig. 77. Generally speaking, a considerable amount of business can be obtained by a proper direction of the soliciting force towards the work of filling up the idle positions as revealed in a study of this character, and considering the amount of invested capital represented by the cable plant, every effort should be made to develop it to the fullest capacity.



TERMINAL FACILITIES RECORD

Date_____

_____ Exchange, _____ Wire Chief.

Cable Number	Terminal Number	Street Location of Terminal.	Terminal Size	Pairs Availab.	Number of Stations of Each Class which can be served without additional pairs							

REPORT OF TERMINAL FACILITIES FOR CONTRACT DEPARTMENT.

Fig. 77.

Cable Facilities Record:—In taking up the work of preparing cable efficiency studies, it is advisable to investigate plant conditions in detail as described above, and then to have the wire chief prepare at intervals of three months a sheet which will show the relative cable and terminal facilities available. If a system of this character is faithfully followed out, it is possible not only to obtain the fullest use of the cable plant, but it also enables additional plant to be planned ahead and in the most economical manner.

CHAPTER V.

CABLE FOR LONG DISTANCE WORK.

The use of the telephone cable for long distance work is yet in the experimental stage, having its inception with the introduction of loaded telephone lines. This chapter is merely an outline of some of the results accomplished, a detailed discussion of the various problems involved being beyond the scope of a work of this character.

Long Distance Cables:—Cable made up with No. 19 B. & S. gauge conductors and having a mutual electrostatic capacity of .054 microfarads per mile was used by most telephone companies to within a few years ago for practically all purposes. With a telephone at each end, about thirty miles of such cable represents the maximum length over which a conversation can be carried. In order to secure good transmission through cables of longer length, it is necessary to increase the size of the wire; and for cables used in conjunction with loading coils, the paired conductors must be very carefully transposed.

Increase of Size of Wires:—The effect of the increase in size of cable conductors on transmission is shown graphically in Fig. 78. Curve "A" represents the transmission efficiency of No. 19 B. & S. gauge .054 mutual capacity cable in terms of itself, ten miles of such cable being equivalent to any other ten miles of such cable, and similarly for any length. Curves "B" and "C" represent the efficiency of cables with No. 16 and No. 13 B. & S. gauge conductors respectively. It will be observed that a twenty mile length of No. 13 B. & S. gauge cable is equivalent to ten miles of standard No. 19 B. & S. gauge cable, or is twice as efficient as the standard cable. This does not mean that the transmission over equal lengths is twice as good in one case as in the other, but that the transmission over a given length of standard 19 gauge cable is as good as transmission over the length of the No. 13 gauge cable.

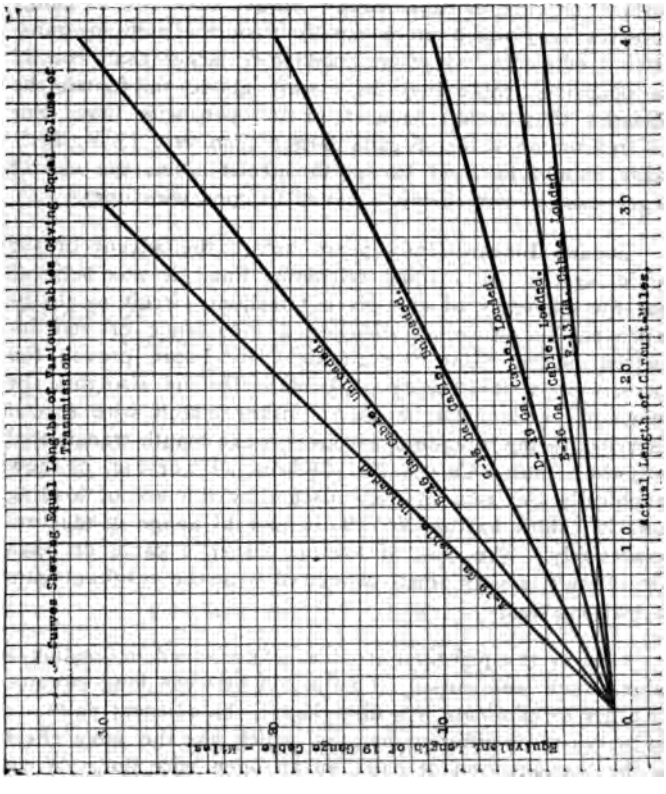


Fig. 78. Curve Showing Equal Length of Various Cables Giving Equal Volume of Transmission.

While it is theoretically possible to go on increasing the size of wire to obtain good transmission over any desired distance there are limits beyond which it is not economical or practical to go in the gauge of circuits for cable work. The cost of cable circuits larger than No. 13 gauge increases very much more rapidly than the gain in transmission efficiency, as when conductors larger than No. 12 are placed in cable they have only about one-fourth the efficiency they would have if on an open wire line. For this reason no cable circuits larger than No. 13 B. & S. gauge should be used except in special cases, the use of larger sizes of wire being confined to open wire lines.

Loaded Lines:—Many years before the advent of the Pupin system of loading telephone lines, it was believed that the efficiency of any given telephone circuit would be improved by uniformly distributed inductance or self induction placed along the circuit. Dr. Pupin proved the correctness of this theory mathematically and also that the inductance coils must be placed in the circuit with special reference to the minimum telephone wave length transmitted over the circuit. Curves "D," "E" and "F" of Fig. 78 show graphically the gain in transmission by the use of loading coils in cables having No. 19, 16 and 13 gauge conductors respectively. The cost of loading either a cable or open wire circuit is very small compared with the resultant gain in transmission.

One of the principal troubles experienced in loading a cable circuit was caused by induction between long circuits. In order to eliminate this disturbance, the adjacent pairs are given twists of different lengths, which has the same effect as the transposition of pairs on an open wire line. When the sides of a cable pair are perfectly transposed with reference to any other conductor in the cable, the capacity between the one side of the pair and any conductor will be equal to the capacity between the other side of the pair and the same conductors. Any difference between these capacities is known as the capacity unbalance of the pair, and specifications for cables which are to be used in con-

nection with loading coils therefore include a test for capacity unbalance.

Transmission Equivalents:—If we desire to express how well a certain circuit will talk, we say that so many miles of the circuit has a transmission efficiency equivalent to one mile of standard No. 19 B. & S. gauge .054 mutual capacity cable. Thus 29 miles of No. 8 B. W. G. open wire copper circuit has a transmission efficiency equivalent to one mile of standard No. 19 gauge .054 mutual capacity cable, etc. Table XII gives the lengths of circuit which have a transmission efficiency equal to one mile of standard No. 19 B. & S. gauge, .054 mutual capacity cable:

TABLE XII.

MILES OF CIRCUIT WHICH HAVE A TRANSMISSION EQUIVALENT TO ONE MILE OF STANDARD CABLE.

Character of Circuit.		Equivalent.
No. 8	B. W. G. Open wire copper, non-loaded	28.8 miles
No. 12	N. B. S. Open wire copper, non-loaded	13.3 miles
No. 14	N. B. S. Open wire copper, non-loaded	8.1 miles
No. 10	B. W. G. Open wire steel, non-loaded	4.0 miles
No. 12	B. W. G. Open wire steel, non-loaded	3.0 miles
No. 22	B. & S. Dry core cable, non-loaded	.63 miles
No. 19	B. & S. Dry core cable, high cap, loaded	.9 miles
No. 19	B. & S. Dry core cable, low cap, loaded	1.0 miles
No. 16	B. & S. Dry core cable, non-loaded	1.3 miles
No. 13	B. & S. Dry core cable, non-loaded	1.8 miles
No. 19	B. & S. Dry core cable, loaded	2.0 miles
No. 16	B. & S. Dry core cable, loaded	4.0 miles
No. 13	B. & S. Dry core cable, loaded	8.0 miles

Another method of comparison is to assume the various circuits to be each one mile long, and to express the transmission efficiency of each as the fraction of a mile of standard No. 19 B. & S. gauge .054 mutual capacity cable to which it *is equivalent.* Expressed in this way the transmissi*equivalents* will be as in Table XIII.

TABLE XIII.

TRANSMISSION EQUIVALENTS OF UNIT LENGTHS OF CIRCUIT.

Character of Circuit.		Equivalent.
1 mile of		
No. 8	B. W. G. Open wire copper, non-loaded	.035 miles
No. 12	N. B. S. Open wire copper, non-loaded	.075 miles
No. 14	N. B. S. Open wire copper, non-loaded	.123 miles
No. 8	B. W. G. Open wire steel, non-loaded..	.205 miles
No. 10	B. W. G. Open wire steel, non-loaded..	.25 miles
No. 12	B. W. G. Open wire steel, non-loaded..	.33 miles
No. 22	B. & S. Dry core cable, non-loaded.....	1.6 miles
No. 19	B. & S. Dry core cable, high cap, loaded	1.11 miles
No. 19	B. & S. Dry core cable, low cap, loaded	1.00 miles
No. 16	B. & S. Dry core cable, non-loaded.....	.77 miles
No. 13	B. & S. Dry core cable, non-loaded.....	.55 miles
No. 19	B. & S. Dry core cable, loaded.....	.50 miles
No. 16	B. & S. Dry core cable, loaded.....	.25 miles
No. 13	B. & S. Dry core cable, loaded.....	.125 miles

CHAPTER VI.

CABLE INSPECTION.

In the economical maintenance of the cable plant, there is no more important factor than inspection. The term as here used covers the examination of the cable plant at intervals for the detection of conditions which are likely to develop dangerous and expensive "trouble." It is evident that by such inspection, and by promptly repairing the weak points in the system, the cable plant can be kept at the point of maximum efficiency and the occurrence of considerable trouble be prevented. This is especially true in the case of inspection for electrolysis prevention.

Organization:—An organization for this work is not necessarily an expensive one. In the case of a small exchange, much can be accomplished by instructing wire chiefs, trouble men, installers, linemen and other employees to observe and report on the various details of plant conditions in connection with their routine work.

Companies operating a number of exchanges may organize a regular inspection department, which can be incorporated with the cable maintenance division or made a distinct department. The former scheme is recommended because the cable testman generally has an idea of the conditions which will develop trouble and his experience in taking care of the various kinds of trouble enables him to put a dollar and cents value on any recommendations he may make.

Inspection Report:—In making an inspection report, it is important to cover all defective conditions existing in the plant, and to make recommendations for repair work or additional equipment as complete as possible. To this end an individual report should be made for each cable, covering the following:

***Messenger* Wire and Cable Clips:**—Recommend the re*placement of* all defective messenger wire and clips, giv*location and* size of cable with approximate length.

Protection of Cable:—Recommend the placing of rubber hose over cables and messenger wires to protect them from high tension crosses as in Fig. 49 and 50. Specify shields for protection of cable from mechanical injury as in Fig. 51.

Bonding and Grounding of Cables:—Make note of the condition of all bonds and grounds and make detail recommendations for additional ones.

Cable Boxes and Terminals:—Make note of the condition of all cable boxes and terminals, stating whether dirty, corroded, unneatly wired and if fuse and lightning arrestor equipment is placed where necessary and in the proper manner. Make recommendations for the repairing of terminals or cable boxes or for additional equipment of fuses and carbons, giving reasons. Recommend the placing of additional cable boxes or terminals, specifying locations and giving reasons.

Condition of Cable Pairs:—Make detail report on the condition of cable pairs by dividing the cable into sections of twenty-five pairs each, and give the number of working and defective pairs in each twenty-five pair section as follows:

Pairs.	Working.	Defective.
1—25	———	———
26—50	———	———
51—75	———	———

Additional Cable:—Recommend the placing of additional cable in all cases in which the present cable has 90 per cent. of pairs defective or in use, giving approximate length of cable required, and reasons for recommendation.

Inspection of Cable Plant for Electrolysis:—The inspection of the cable plant for the detection of electrolysis differs from other inspection work in that it cannot be carried out in accordance with any fixed rules or methods of procedure.

The periodical inspection of cables in manholes and the measurement of relative potentials of cables, surrounding *earth, water and gas pipes*, and measurement of direction *and amount of flow* of current in cable sheaths is essential.

Measurement of Differences in Potential Between Cables and Ground:—*The inspector* should be provided with a

Weston low reading voltmeter reading in both directions from zero in the center of the scale, as in Fig. 79. The Duplex type of instrument is most convenient for these tests, although a low reading direct current voltmeter such as the Weston Model 45, can be employed provided the zero is located at the center of the scale.

Fig. 79. Weston Voltmeter.

A light, sharp pointed, iron rod four or five feet long is connected to the binding post "C" of the voltmeter by means of a flexible conductor, and a similar rod is connected to the binding post "G." In making measurements of potentials, the rod connected to "C" is held continuously on the cable sheath in the manhole, and the other rod is held successively on the ground in the bottom of the manhole, on the sheaths of other cables, and on adjacent underground structures, as in Fig. 80. The readings obtained should be *carefully* recorded, and if the results indicate that the cable *sheath is* positive to ground at any point, careful and prom*attention* should be given to the removal of this conditio

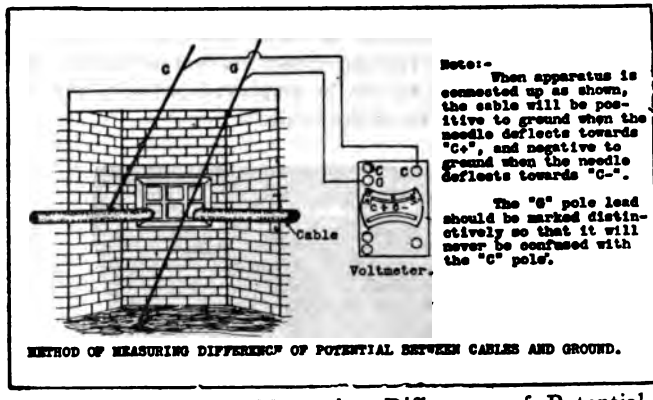

C
G
Cable
Voltmeter.
Note:-
When apparatus is connected up as shown, the cable will be positive to ground when the needle deflects towards "C+", and negative to ground when the needle deflects towards "C-".
The "G" pole lead should be marked distinctively so that it will never be confused with the "C" pole.
METHOD OF MEASURING DIFFERENCE OF POTENTIAL BETWEEN CABLES AND GROUND.

Fig. 80. Method of Measuring Difference of Potential Between Cables and Ground.

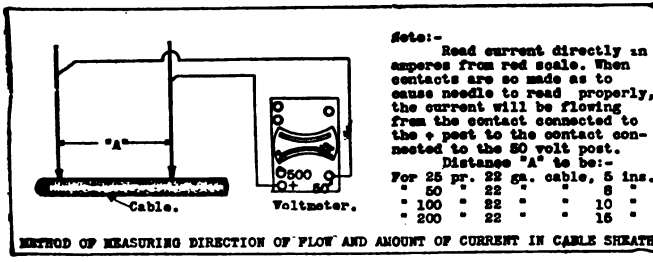

"A"
Cable.
Voltmeter.
Note:-
Read current directly in amperes from red scale. When contacts are so made as to cause needle to read properly, the current will be flowing from the contact connected to the + post to the contact connected to the 50 volt post.
Distance "A" to be:-
For 25 pr. 22 ga. cable, 5 ins.
" 50 " 22 " " 8 "
" 100 " 22 " " 10 "
" 200 " 22 " " 16 "
METHOD OF MEASURING DIRECTION OF FLOW AND AMOUNT OF CURRENT IN CABLE SHEATH.

Fig. 81. Method of Measuring Direction of Flow and Amount of Current in Cable Sheaths.

Measurement of Current in Sheath:—In measuring the amount and direction of flow in the cable sheath, the contact rods are connected to the fifty millivolt scale of the voltmeter and held on the cable sheath, as shown in Fig. 81. *The distance along* the cable sheath between the two rods *should vary with the* resistance of the sheath, and for the *different sizes of cable,* is as given in Table XIV.

TABLE XIV.

DISTANCE BETWEEN ELECTRODES FOR MEASUREMENT OF CURRENT IN SHEATH.

Size of Cable.	Distance Between Rods.
25 Pair—22 Gauge	5 Inches
50 Pair—22 Gauge	8 Inches
100 Pair—22 Gauge	10 Inches
200 Pair—22 Gauge	15 Inches
400 Pair—22 Gauge	21 Inches

The cable sheath should be made bright with a piece of emery paper at all points of contact.

Insulation Joints:—In all cases where cable sheaths are found to be positive to ground, an examination should be made to determine if the trouble is caused by the contact and grounding of the cable with foreign pipes in manholes or with other iron work, such as iron trestles or bridges. A great deal of trouble is often experienced in such cases by current feeding into the cable from these structures. All cables which are necessarily in contact with iron work used as a return for a trolley current, should be provided with an insulation joint at each end of the structure. The sheaths of the cable sections on each side of the structure should be made continuous by means of an insulated copper bond wire carried past the point so insulated, as in Fig. 82. The method of making an insulation joint is as follows:

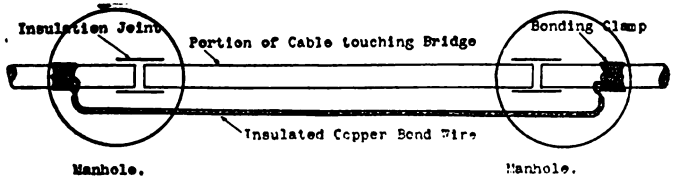


Fig. 82. Method of Bonding Cables Past Insulation Joints.

The joint is made in the manhole nearest the bridge or *trestle and* located in a straight portion of the cable where *it will not* be subjected to strains. At the center of

cable on which the joint is to be made, a ring of lead sheath ¼ of an inch wide is removed and 4 inches on each side of this ring two small openings are made. As much paraffin is poured into the cable at these points as it will absorb, and the small holes are closed and soldered. At the point where the ring of sheath has been removed, lamp wick saturated with hot paraffin is wrapped around the cable core in such a manner as will prevent the two sections of sheath from coming in contact. Two layers of tape are then wrapped around the wicking and for about 3 inches on each side of it, and a heavy coat of asphaltum paint is applied to the tape. Over this coat of paint is wrapped a double layer of tape, followed by a heavy coat of asphaltum paint, the process being repeated until 8 double layers of tape are applied. The direction of the tape is reversed on each layer, and each layer overlaps the preceding one. A split lead sleeve is then placed over the tape, care being taken that it does not come in contact with the cable sheath at the insulated end. The seam is now soldered and a wiped joint made at the uninsulated end of the sleeve. The insulated end is wrapped with tape applied in opposite directions, and the whole joint given two coats of asphaltum paint. The method of making this joint is shown in Fig. 83.

Method of Making Cables Negative to Ground:—The most approved method of making cables negative to ground is to run a bond wire from the cable to the negative bus bar of the power switchboard. When the expense of this method is prohibitive, the bond wire may be connected with satisfactory results to a point on the negative return feeder or trolley rail. The point of attachment to the cable is determined by differences in potential, and should be so located and the bond wire of such size that there will be a considerable flow of current from the cable sheath to the negative return system.

Size and Character of Bond Wires:—The bond wire *must have a less resistance* than the resistance between the *cable sheath and the* earth where the cables are positive, *but this resistance* should be only low enough to make the

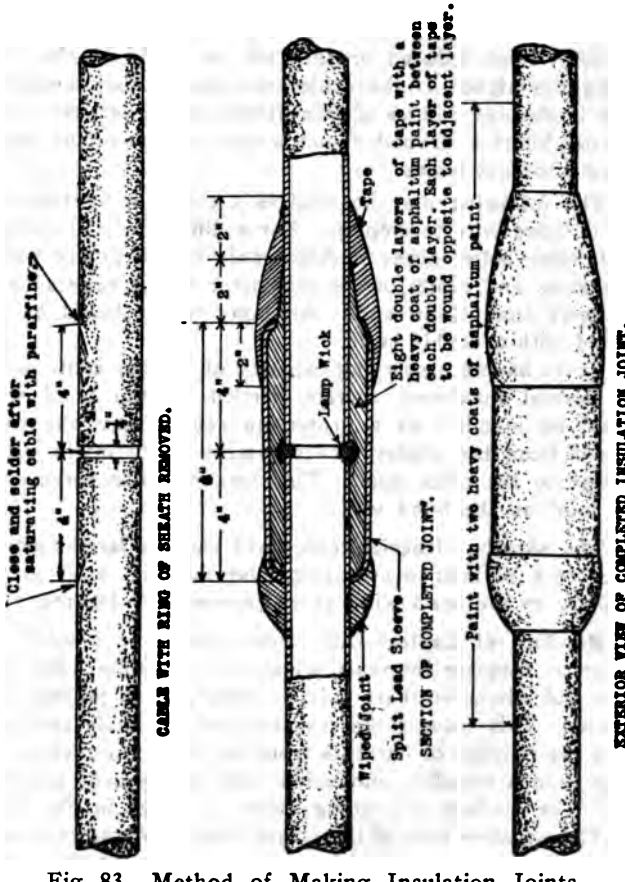

Close and solder after saturating cable with paraffine
4"
4"
1"
CABLE WITH RING OF SHEATH REMOVED.
2"
2"
2"
4"
4"
4"
Lamp Wick
Tape
Eight double layers of tape with a heavy coat of asphaltum paint between each double layer. Each layer of tape to be wound opposite to adjacent layer.
Wiped Joint
Split Lead Sleeve
SECTION OF COMPLETED JOINT.
Paint with two heavy coats of asphaltum paint
EXTERIOR VIEW OF COMPLETED INSULATION JOINT.

Fig. 83. Method of Making Insulation Joints.

cable slightly negative. If the cable sheaths are made too strongly negative, very large currents may flow into the cables, and generate chemicals which react to destroy the lead sheathing. This action takes place when the currents are very much reduced or shut off, as would be the case during the night. If the cables are too strongly negative, there is also the danger of arcs being formed between them and neighboring grounded conductors, such as pole pipes or water or gas mains.

The following may be used as a guide in figuring the size of bond wire to employ: For a difference of potential of 10 volts between the negative pole of the power house generators and cables, use a conductor whose resistance is not more than ½ an ohm. All bond wires should be insulated with a double braid.

Fuses having a carrying capacity of 100 per cent. above the normal maximum current carried by the bond wire should be installed as a protection against any abnormal current from the trolley feeder system which might cause damage to the cable plant. This fuse will also serve as a test joint on the bond wire.

The sheaths of aerial cables will carry a large amount of current without overheating, and may be used as an auxiliary to the bond wire where conveniently located.

Bonding of Cables:—All cables should be bonded together at frequent intervals, usually at manholes 1,000 feet apart and whenever there exists a difference in potential of .2 volts. This reduces the resistance of the cable and prevents the passage of currents from one cable to another by other than a metallic connection, with consequent electrolysis. The method of bonding cables is shown in Fig. 73.

The negative pole of the power house generators should always be connected to ground. If this is not done, the rapid destruction of cables and other underground structures will result.

Electrolytic Survey:—At least once a year a systematic measurement of differences in earth potential throughout the change area should be made. This is accomplished by

measuring the differences of potential between a ground connection near the power house and negative return feeder attachment, and representative points in the cable district.

Inspection Report File:—The inspection reports should be filed in the inspection division office under the exchange and cable number, together with a brief statement of the work done as a result of the recommendations made. Copies of each inspection report should be sent to the department having charge of new work or reconstruction and also to the department having charge of cable trouble location and repairs.

It is especially important that the notes of all electrolytic inspections be preserved, as the data acquired from repeated inspections becomes of great value.

CHAPTER VII.

CABLE TROUBLES AND TESTING.

By analyzing the causes of trouble in telephone cables, the most effective and economical method of repair can be decided upon, as well as measures taken to prevent the recurrence of the trouble.

Holes Through Lead Sheath:—A majority of cable troubles are traceable to holes through the lead sheath of the cable, and the consequent destruction of the paper insulation by the absorbtion of moisture.

Defective Plumbing:—Holes are often caused by defective plumbing. In making a wiped joint, unless the cable sheath is properly tinned, a small crevice is left between the sheath and wiping metal. Cracks are also caused by moving the wiping metal around after it has started to set.

Burns:—Another frequent source of trouble is from holes caused by burns between the cable and messenger wire. The messenger wire comes in contact with a high tension wire and carries this high potential current along to some point of partial contact with the cable, forming an arc between the cable and messenger wire with resultant damage to the lead cable sheath. This trouble is prevented by bonding the cable and messenger wire together at intervals of one thousand feet along the cable. See Chapter III, Cable Construction, Bonding and Grounding.

When open wire lines of over one-half mile in length are connected to an aerial cable, the connection should be made through fuses and carbons. If the cable is not protected in this manner lightning may strike an open wire lead and follow it into the cable. The lightning will pass to ground at some point offering least resistance for its passage, as at a bend in the cable, but in so doing burns off the conductor that brought it in and sometimes others and a *hole through the lead sheath.* If high tension wires become *crossed with the open* wire lines, the effect is similar to that *of a lightning stroke,* although usually not so severe.

Vibration:—When cables are carried across bridges, vibration sometimes causes breaks to occur in the lead sheath. This trouble is prevented by either supporting the cable from the messenger wire by means of extra long cable clips, or by placing the cable in a smooth pipe across the bridge.

Bullet Holes:—Occasionally trouble is caused by bullets being shot through the cable sheath. This causes crosses and sometimes open pairs, and moisture is also absorbed into the cable.

Mechanical Injuries:—Cables sometimes suffer from mechanical injuries, such as chafing on trees or other objects, and spur or nail holes caused by careless workmen.

Defective Potheads:—Trouble is often caused at potheads by compound being poured in around the rubber covered wires while very hot. This softens the rubber insulation and causes short circuits. On the other hand, if the cable compound does not flow freely into all parts of the pothead, a leaky terminal may result.

Open Wires:—Trouble from open wires may be caused by lightning and high tension burns as before mentioned, by bullets cutting through cable pairs, and by wires being poorly spliced either at the factory or by splicers. Another cause of open wires in cables with No. 22 B. & S. gauge conductors is traceable to the use of a knife by the splicer in picking out pairs. If the knife nicks the wire even very slightly, a small strain on the cable will cause the wire to open.

Wire Showing Abnormally High Resistance:—A loose joint in a cable splice will cause the resistance of a cable wire to measure higher than it should be for the length of cable.

Frozen Cables:—Water frozen in cables becomes an insulator, hence trouble will come and go in a cable, depending on whether the weather is warm or freezing.

Defective Paper Insulation:—Boiling out a splice many times has a tendency to rot the insulation. If work has to be done on a splice of this sort, it is more economical to cut in a new splice or a short piece of new cable.

Electrolysis:—Cable sheaths are normally of very low resistance, and in cases in which this resistance is lower than that of the earth or adjacent underground pipes, grounded return currents from electric railway systems will flow through the sheath on their way to the power house. Electrolytic action takes place where the currents leave the cable and pass to earth, producing a peculiar "pitted" appearance upon the cable sheath and finally destroying it. The amount of electrolytic action depends upon the proximity of the cables to, and the distance the cables parallel the electric railway, the conductivity of the earth, and the proximity to the cables of other underground structures.

Cases have been noted in which the anchors of aerial cables were eaten off by electrolysis. This is prevented by keeping the anchor guys free from electrical contact with the messenger wires.

The measures to be taken for the prevention of electrolysis have been discussed in Chapter VI. "Cable Inspection."

Maintenance Organization:—In the case of a large territory a suitable organization for cable maintenance would consist of a maintenance office at the center of the district and an adequate force of traveling testmen and splicers.

Reports of Cable Trouble:—Cable trouble should be reported by telephone direct to the cable maintenance office by the local exchange manager. In making his report, the manager should give as much information as possible regarding the location and extent of the trouble, and follow his telephone message by a written report made out on a form similar to that shown in Fig. 84. The cable maintenance office immediately communicates with the testman who happens to be nearest the exchange where the trouble occurred, and sends him a "Report of Cable Trouble" (Fig. 85) bearing as much information regarding the trouble as can be secured, together with a cable map of the exchange giving distances between pole centers or manholes. Upon completing his repair work the testman fills out this form with a detailed statement of the trouble cleared, condition of cable pairs, and the time and expense incurred by himself and others in repairing the trouble. The completed re-

Manager's Report of Cable Trouble.

.....Exchange. Date.....
To Testing Division:
Confirming telephone report of.....
..... A. M. / P. M.
Cable No..... Nature of trouble,.....
.....
.....
Number of subscribers out of service.....
Remarks .....
.....
.....
Signed.....
Manager.

Fig. 84.

ports are filed in the cable maintenance office under the exchange and cable number, and may be quickly referred to in looking up old cases of trouble. At the end of each month a statement is prepared from this file giving the causes of each case of trouble and the cost of clearing it.

By keeping a continuous record from month to month for a given territory, the relation between the growth of the plant and the changes in the maintenance costs can be compared, and a close supervision kept over the maintenance expense. Also by comparing maintenance costs for one territory with those of another territory, provided a common system of records and work is adopted, information can be obtained as to the relative efficiency from a cost standpoint of the maintenance organizations in these territories.

Should trouble be caused by defective plant conditions, such as improper bonding or grounding of the cable, the file of inspection reports before referred to can be consulted and whether the fault is caused by the inspector not repo

CABLE TROUBLE REPORT.

_____ Exchange.

Date_____ Cable No._____

TROUBLE REPORTED:
Time,_____ Nature of,_____

TROUBLE LOCATED:
Time,_____ Nature of,_____

Pairs in trouble,_____ Location,_____

Pairs used to locate trouble,_____

CABLE OPENED:
Number of places,_____ Location of each,_____

Causes of trouble,_____

How repaired,_____

Trouble left in cable, if any,_____

REMARKS:_____

Time spent on job,_____ Carfare,_____ Expressage___

Team hire,_____ Material used,_____

I find trouble cleared,_____ Wire chief.

_____ Splicer. _____ Testman.

(Reverse side of Cable Trouble Report)

MATERIAL AND EXPENSE.

Splicers & Helpers	Hours	Rate	Board	Carfare	Misc.	Dray	Amount	
Testman	Days							

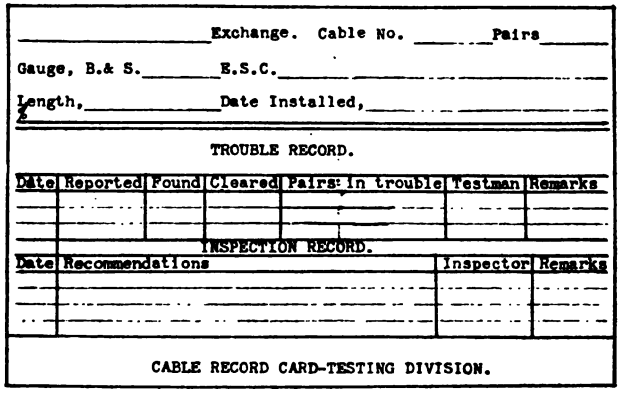
Material	Quantity	Amount	Remarks

Testman.

CABLE TESTING DIVISION REPORT OF CABLE TROUBLE.

Fig. 85.

ing the defect, or by the negligence of other departments in not making repairs in accordance with the recommendations of the inspection division, the responsibility may be easily fixed.



_____Exchange. Cable No. _____Pairs_____

Gauge, B.& S._____E.S.C._____

Length,_____Date Installed,_____

TROUBLE RECORD.

Date	Reported	Found	Cleared	Pairs in trouble	Testman	Remarks

INSPECTION RECORD.

Date	Recommendations	Inspector	Remarks

CABLE RECORD CARD-TESTING DIVISION.

Fig. 86.

The form shown in Fig. 86 is used in the cable maintenance office as a ready reference record of each cable, and bears an abstract of the inspection report and cable trouble reports.

Cable Testing Apparatus:—A cable testing set for fault location consists of a Wheatstone bridge, galvanometer, and battery wired up to a switch for making different tests, the whole being mounted in a carrying case.

Fig. 87 illustrates diagramatically a type of what is known as the "Plug Decade" testing set, manufactured by the Leeds & Northrup Company, a detailed description of which is as follows:

The rheostat is arranged on the decade plan. This requires but a single plug for each row of resistances, which makes it very convenient to manipulate, and has the very decided advantage that the resistance is read off directly from the position of the plugs. As will be noted from the drawing, the blocks are in pairs and each pair is mecha

ically independent of the other blocks. There is consequently no danger that a plug contact will be loosened by removing a plug near it.

The ratio coils are arranged on the plug-in plan and are reversible.

Blocks are provided so that connections can be quickly made for locating faults by both the Murray & Varley Loop Tests.

Binding posts are provided so that an outside battery can be used, or an outside galvanometer, thus providing for

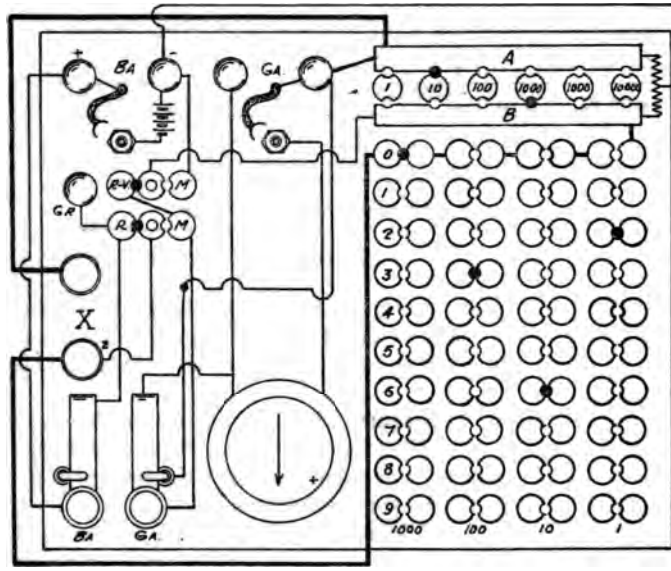


Fig. 87. Plug Decade Test Set.

the possibility of using more battery in case faults are to be located where there is a very high resistance in the fault, and also for the possibility of using a highly sensitive outside galvanometer in similar cases. The set contains four cells of battery, and a sensitive portable galvanometer, which will deflect one division with one volt through a resistance

of about one-half megohm. The battery is ample and the galvanometer sufficiently sensitive to meet all ordinary requirements.

The method employed in the bridge arm arrangement avoids the use of a commutator, such as is used in the post-office type of bridge having reversible bridge arms, thereby eliminating the use of two extra plugs. Another decided advantage of this bridge coil arrangement is the fact that the formula for the unknown resistance is always $\frac{A}{B} R$ regardless as to whether a particular coil is used in the A arm or B arm. The bridge has six coils 1, 10, 100, 1,000, 1,000, 10,000 ohms which are adjusted to an accuracy of 1/20 per cent.

The rheostat has four decades with values of units, tens, hundreds and thousands, there being nine values in each. The accuracy of adjustment is 1/10 per cent. The coils are arranged upon a plan using but 4 coils to each decade.

In the "Dial" form of test set a dial wheatstone bridge and rheostat is substituted for the plug system. Fig. 88 illustrates such a set, made by the Thompson-Levering Company.

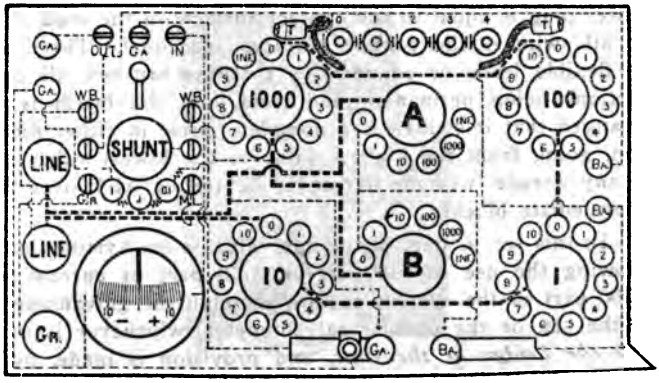


Fig. 88. Thompson-Levering Dial Test Set.

This set is of the latest improved type of switch construction, and is adaptable to all tests in which the Wheatstone Bridge conditions may be used.

The rheostat is composed of four dials of ten coils each. These dials have values of units, tens, hundreds and thousand ohm coils, which are guaranteed accurate to 1/10 of 1 per cent. The bridge arms A and B have values of 1, 10, 100 and 1,000 ohms in each arm, guaranteed accurate to 1/20 of 1 per cent. The accuracy of this adjustment makes the results as close as are practicable, and the values of the arms give a very wide range of measurement.

The switches are of a special design, of the quick make and break style, allowing the tester to make changes rapidly in performing the different tests to be made, thus making it very easy to manipulate.

The rheostat dials have a special design of brush, which is entirely new, and which gives a uniform spring contact, both on the arm running over the blocks, and also on the center ring. The brush is laminated with a number of laminations of spring phosphor bronze, the ends are carefully ground, and slide over the contacts evenly and smoothly, and the contact resistance is negligible. The brush is set at an angle, so that in swinging over the blocks, it does not mark or line the blocks. The contact surface on the center plug is equal to the contact surface on the stud, thus on all switches the contact surfaces are equal. There are no flexible leads or connections to these brushes, all connections being permanent and rigid, and the brush is so arranged that it swings in a complete circle in either direction, going from the highest value to the lowest value coil in any decade, without having to be turned back over the intermediate blocks.

In this set, as part of the apparatus, is an Ayrton shunt, allowing the use of full current, 1/10 part of current, or 1/100 part of the current to flow through the galvanometer of the set, or the outside galvanometer, whichever is used with the bridge at the time, and provision is made, by a quick make and break switch, to use either inside or outside galvanometer. The galvanometer itself is of the D'Arsonval

type, and has a very high sensibility. The magnet is made of special magnet steel, carefully aged, and is permanent and strong. The galvanometer is very quick and positive in its action, and the construction and design is such that it is extremely dead-beat, making readings very easily and quickly. The galvanometer key is arranged with a short circuit device, which also helps to bring the needle to rest promptly. The galvanometer scale has thirty millimeter divisions with center zero, is well lighted and easily read, and the scale is uniform, making the set well adapted for insulation measurements.

The batteries in the case consist of four commercial size cells, and these cells are replaceable by removing four small screws, which releases the cell block in which the new cells are put, this block is then slipped back into place and screwed in, the operation taking but a very few minutes, and the rest of the set being entirely undisturbed.

The size is, 9¼ inches long by 5¾ inches wide by 5½ inches deep, and the set complete, as taken out by the tester, weighs 7¾ pounds.

Fig. 89. "Wireless" Cable Tester.

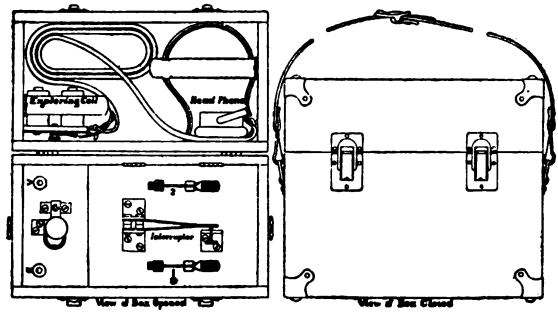


Fig. 90. Matthews Telefault.

Fig. 89 shows an instrument called the "Wireless" Cable Tester, manufactured by the Electric Specialty Company. This instrument operates from mutual induction and can be used for locating all cable troubles except "opens." The apparatus consists of a means of producing a current in a circuit, and then tracing the circuit by means of an exploring coil and a telephone receiver. This device requires no technical knowledge whatever to operate it, and has proven satisfactory to hundreds of telephone companies.

Fig. 90 illustrates diagrammatically another instrument of much the same class, known as the "Telefault," and manufactured by W. N. Mathews & Brother, space not permitting a detail description.

Methods of Fault Location:—The following methods of procedure in locating troubles have reference to the use of a testing set making use of the Wheatstone Bridge principle.

Preliminary Voltmeter Test:—Before proceeding to make *fault locations, the* insulation resistance of all conductors in *the cable should be* measured by means of a sensitive high *resistance voltmeter* and battery in series, using the follow*ing formulae:*

Let X equal resistance of cross or ground in ohms.
R equal resistance of Voltmeter.
D equal deflection of Voltmeter without x in circuit.
D^2 equal deflection of Voltmeter with x in circuit.

Then X equals $R \frac{(D-1)}{(D^2)}$

One terminal of the voltmeter is connected to the conductor under test and the other touched first to ground and then to the other wires in the cable. This test will show whether the conductor is grounded or crossed with any other conductor in the cable, and if crossed will tell the wire with which it is crossed. A record should be made of the reading of each conductor.

Terminal Trouble:—Should the trouble be on only a few pairs, it may be found at some terminal where these pairs are tapped out. The causes of terminal trouble may be dirt or solder grounding the terminal, the pair may have a dead service loop connected to it, or the tap cable may be grounded on the terminal base or have some defect in its sheath.

Locating Trouble on a Grounded Line:—If the trouble does not locate at a terminal, a clear wire and a badly grounded one should be connected together at the outer end of the cable, and the resistance of the loop measured up as follows:

Resistance Measurement:—Fig. 91.

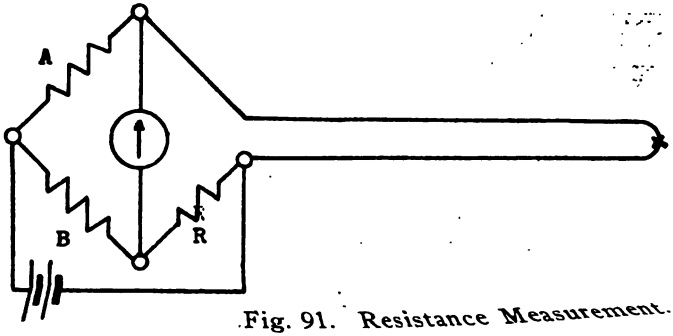


Fig. 91. Resistance Measurement.

The resistance of the loop (x) equals $\frac{A}{B} \times R$. The resistance so found must be multiplied by 31 for 22 gauge cable and 61 for 19 gauge cable, as these figures represent the length in feet of a loop whose resistance is 1 ohm; this result should be within 3 per cent. of the actual length of the cable. If it does not come within this limit, an error has probably been made, and another combination of a good and bad wire should be tried. Should this measure up the same as the first loop, the cable measurements are very likely wrong.

If the loop resistance measurement appears correct, the switch of the cable testing set should be thrown to the Murray position, and a fault location taken, using the following formulae:

Improved Murray Loop Method:—Fig. 92.

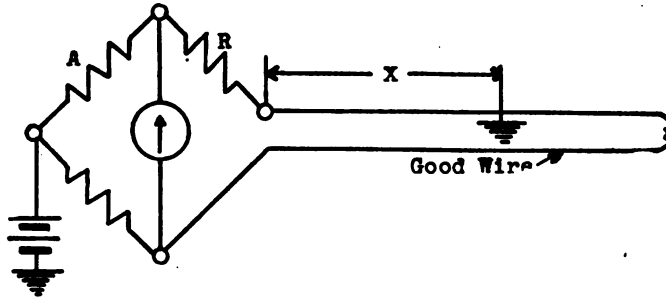


Fig. 92. Murray Loop Test.

A = 100.
R = 0.
X = distance to fault in feet.
l = *length of* cable in feet.

Then $A : B = X : 21 - X$, or $X = \frac{21\,A}{B+A}$

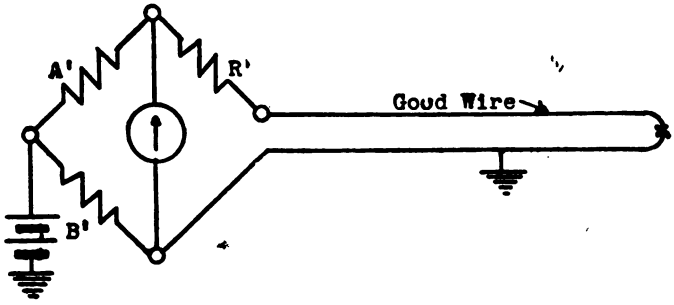


Fig. 93. Check Measurements, Murray Loop Test.

Check Measurements:—Fig. 93.

$$A'=100. \quad R'=0. \quad B' = \frac{AA}{B} = \frac{10{,}000}{B}$$

In order to insure a minimum effect from disturbing currents, ground connection should be made only on the sheath of the cable under test.

In cases of disturbances from polarization, a reversing key placed in the battery circuit should be frequently reversed.

The leads should be as short as possible, of the same length, and of the same size wire as the cable conductors. The length of the two leads should be included in the 21. Then the result x will include the length of one lead. If B equals 100, fault is at distant cable end, if B equal 10,000, fault is at the testing end.

Good and bad wires should be a pair if possible, as the wires in two pairs may not be the same length, due to the fact that one wire may twist around the outside of the cable core while the other may be in the center.

Sufficient battery should be used to give a good deflection of the galvanometer needle, but too much battery will heat up and increase the resistance of the bridge coils, and thus not give a true reading.

At least three readings should be taken, using different pairs if possible.

Case of a Very Slight Ground:—In the case of a very slight ground, a more sensitive galvanometer or more battery should be employed. The latter course is recommended because of the liability of trouble from induced currents when using a highly sensitive galvanometer. A ground of this sort can often be increased or removed by putting ringing generator current through it.

Multiple Cables:—If a multiple cable with two or more long branches is in trouble the first location should be taken with the wires looped at the end of the longest branch. When the trouble locates at the multiple of the main cable with a branch cable, it may be anywhere in the branch, therefore another location should be taken between the end of the branch and the office. This should give the exact location.

Locating Trouble on a Crossed Wire:—Should the wire be crossed with another wire instead of being grounded, the same method of locating the fault can be used, except that one of the crossed wires is connected to the ground post and the other is used for the side of the loop. By reversing these wires, and using the side that was employed for a ground connection for the loop, and the other crossed wire in place of a ground connection, a check location can be obtained. The resistance of the loop should first be measured to see that connections are properly made and that the length agrees with the resistance.

Location by Resistance:—When wires become crossed there is sometimes practically no resistance between the wires at the point of contact. By measuring the resistance between the wires and multiplying this resistance by 31 for 22 gauge cable, or 61 for 19 gauge cable, the distance of the fault from the office will be obtained. In case the cross has some resistance in it, the trouble will locate farther away than it actually is, but will never be much beyond where the location places it. A cable will sometimes become burned from a high tension cross which will open up the wires from one end and fuse them together at the other end, then this test is the most practical one.

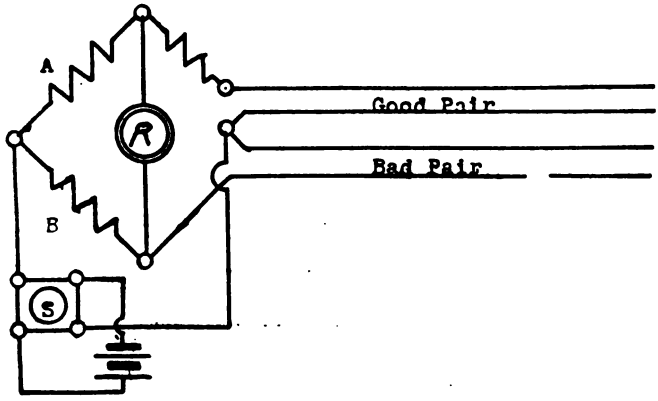


Fig. 94. Open Wire Test.

Locating Trouble On an Open Wire:—If an open wire tests clear of grounds and crosses, the fault can be located as shown in Fig. 94. After making connections the reversing switch S is rapidly rotated and A adjusted until no sound is heard in the telephone receiver R.

B = ratio arm of bridge.
A = variable resistance of bridge.
1 = length of cable in feet.
X = distance to fault in feet.

$$\text{Then } X = \frac{B}{A} \times 1$$

The accuracy of this method depends upon the capacity of the two wires being equal.

Locating* Trouble When an Outside Wire Has to Be *Used:—*If all* the wires in a cable are grounded, an outside *wire of any* convenient size should be run which will be

from grounds. After the wire is strung the following method of locating trouble should be used. Fig. 95.

1 = length of cable in feet.
A = 100.
R = 0.
X = distance to fault in feet.
r = resistance in ohms of bad wire.
S = resistance in ohms of loop (good and bad wire).
D = reading of instrument.

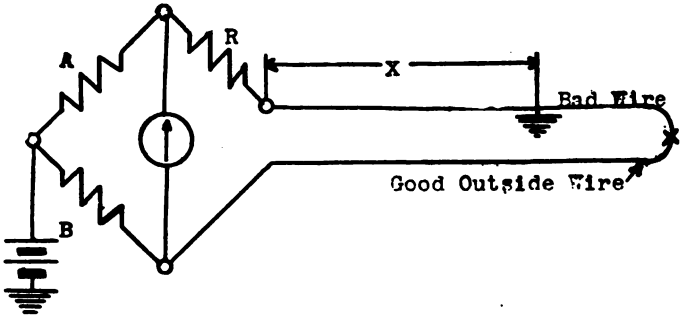


Fig. 95. Locating Trouble When an Outside Wire Has to be Used.

$$\text{Then } X = \frac{A}{r} \times \frac{1}{D+A} \times \frac{S}{r} = \frac{S}{r} \times \frac{1\,A}{D+A}$$

r is found by measuring up the loop resistance of the bad wire with its mate and dividing by two.

Locating Trouble in Frozen Cables:—When water gets into a cable and freezes the insulation resistance of the conductors will measure the same as if the cable were clear. To locate this trouble, the cable should be heated up with a furnace passed along it. A sensitive high resistance voltmeter and battery should be placed in series between the ground and one or more of the cable conductors. As soon as the section with the moisture in it is heated there will be a deflection of the voltmeter needle. If not found in

this way the trouble should be left for warm weather, when it can be located in the usual manner.

Locating Trouble When Loop Is Made up of Different Sized Conductors:—It often happens that a piece of 19 gauge cable will be spliced into a cable with 22 gauge conductors or vice versa. In this case the usual method of fault location would give a false reading. This can be avoided by making a diagram of the cables, showing the section lengths, terminals, important streets, the size of the conductors and the number of pairs in the cable. The section lengths for 19 gauge cable can be used in the formulae for fault location, but those for 22 gauge cable should be multiplied by 2, as the resistance of 22 gauge wire is practically double that of 19 gauge.

Varley Loop Test:—The Varley loop test is much used for open wire work, but the Murray loop is considered more advantageous for cable trouble location.

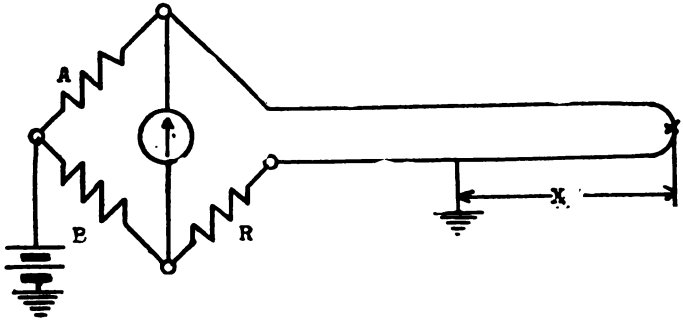


Fig. 96. Varley Loop Test.

Make B = A.

Let X = distance of fault from end.

l = length of pair in feet.

C = resistance of loop.

R = resistance required to balance or resistance of lo
beyond fault.

$$\text{Then } \frac{\frac{1}{2}R}{\frac{1}{2}C} = \frac{X}{1} \text{ or } X = \frac{1\ R}{C}$$

$\frac{C}{1}$ = resistance of 2 feet of wire.

$$x = \frac{R}{\text{Resistance of 2 feet of wire.}}$$

DIFFICULTIES IN MAKING MEASUREMENTS.

Restless Galvanometer Needle:—Heavy currents flowing near the galvanometer are indicated by the galvanometer needle being restless all the time. This can be remedied by setting the magnet of the galvanometer at right angles to the disturbing conductor. If the disturbance is caused by a trolley wire, the galvanometer needle should be set in the direction it would take if placed very near the conductor or along the magnetic lines of force. The needle can be set in any desired position by creating a new magnetic field near it, this being done by placing some small article of iron or steel adjacent to it. Care should be taken that the new magnetic field is not so strong as to impair the sensitiveness of the needle.

If the galvanometer needle appears to be restless as soon as the galvanometer key is pressed, foreign currents are probably flowing in the loop under test. If the disturbing current cannot be shut off, another loop should be tried.

A restless galvanometer needle may sometimes be caused by induction from an adjacent power wire when an outside wire is used for testing purposes. This can sometimes be cured by using another wire for the loop.

Two Faults:—Two faults on a conductor will often *cause a restless galvanometer* needle, due to a difference of *potential between them.* A measurement can sometimes be *secured by balancing* the needle, taking a reading, then *reversing the battery,* balancing the needle and taking a sec-

ond reading. The approximate true reading will be the average of the two readings. Should there be two faults in the cable the test will locate the apparent trouble somewhere between the two real troubles. If the cable is opened and trouble found both ways from this opening, a new location should be made from the first location to where the cable is open, cutting off the ends of the test pairs beyond the opening. Extra care should be taken on this location, at least five readings being taken. The cable should be opened at the place indicated by the test, after closing the one already opened. After the one case of trouble has been cleared, the cable will have but one case of trouble in it, which can be cleared in the usual manner.

Disappearing Ground:—Sometimes while trying to make a location, the fault will disappear. This is usually caused by the battery current from the testing set turning a slight moisture ground into gas. Often by waiting for a short time the ground will reappear, or can be located by using more battery and taking a quick reading. The ground can sometimes be increased or burned out by ringing generator current applied to the faulty wire.

METHODS OF CABLE REPAIR.

Splicer's Work:—Upon receiving the report of cable trouble the testman and splicer should proceed at once to make locations, while the helper sees that tools and material are in readiness for the splicer to begin work. Sometimes the trouble can be found before the tools are unpacked and if it happens that the trouble is of such nature that no tools are required for its repair, the tools can then be shipped to the next job without unpacking.

The splicer should go to the outer end of the cable, or to a terminal designated by the testman, and call the testman over a pre-appointed pair. If he cannot reach the testman in this way he should call the central office on another pair and get into communication with the testman as quickly as possible.

The splicer should inspect the cable as he walks along it, and report any condition that might have caused trouble to the testman. If the cable pair to be tested has subscriber lines working on it, they should be removed and marked so that they can be properly replaced after the test is made. As soon as the testman has located the trouble, the splicer examines all wiped joints and soldered seams near the location. If the trouble locates near a terminal and there are only a few pairs in trouble, it will probably be found in the terminal or cable box, providing the pair is tapped out at that terminal. If the trouble is not found in this way, the splicer should make a close inspection of all parts of the cable one hundred feet on each side of the location. This is done from a cable car as in Fig. 97, loaned by the F.

Bissell Company. If the trouble is not found by this inspection the cable should be opened up at the sleeve nearest the location. The sleeve can be removed by unwiping the joints at either end and slipping it along the cable, or by cutting it off, in which case a new split sleeve would be required. The former method is to be preferred not only on account of the saving in material but because it is difficult to secure

seal a seam in a split sleeve, and being the weakest part of the sleeve, the seam is liable to crack if slightly strained.

After the lead sleeve is removed the muslin wrapping should be cut away from around the splice and hot paraffin poured over it to loosen up the wires for hunting pairs, taking particular pains while so doing not to disarrange the splice any more than is absolutely necessary. All the pairs to be tested should be connected up with generator if possible, so that it is necessary to hunt only once through the splice. All pairs opened should be carefully marked so as to avoid making mistakes in re-connecting them.

Removal of Moisture:—The most general trouble is that caused by moisture being absorbed into the cable. This is removed by boiling out the core with hot paraffin. After the moisture is boiled out of a splice the insulation resistance of the conductors should be measured with a voltmeter and battery. Occasionally the conductors will show low insulation on account of the splice being very warm. It sometimes happens that when water has laid in the splice for a long time corrosion from the copper wires will have injured the insulation, and the trouble will not yield to repeated boilings. This trouble can usually be cleared by picking out the bad pairs and separating them through the splice.

After clearing the trouble the splice should be neatly arranged and thoroughly boiled out, and the lead sleeve wiped on in the usual manner. The same care must be exercised in making splices on maintenance work as in construction. See specifications for Cable Splicing, Chapter III.

Defective Potheads:—When a pothead becomes defective it is considered economy to cut in a new pothead on the end of a piece of cable long enough to reach a point where a splice can be made to the cable, rather than to try to repair the damaged pothead.

This piece of cable is then cut on to the old cable, and the old pothead and a similar length of old cable removed. For method of making Potheads, see Chapter III.

New Section of Cable:—The usual method of testing an *splicing in* a new section of cable is to bridge the new ca *on to* the old one at the splice farthest from the ca

office. The other end of the new cable is fanned out on a temporary connecting board, the left side of each pair being placed on a nail, the right side of the pair being insulated from all other wires and ground.

The splicer then proceeds to test out the pairs and splice in the new section to the working cable at the splice nearest to the central office where the temporary connecting board is located. After all the pairs are tested out and spliced, the splicer returns to the splice fartherest from the central office, cuts off the old cable and splices the new one through in the usual manner. Before closing up the lead sleeves the conductors should be tested through from the central office to the terminal, in order to determine if all the pairs are perfect.

Should a section of cable be so badly grounded that it is impossible to test through it, the bad section should be cut out and the new piece to replace it spliced in at one end. At the other splice all conductors should be tested out both ways, numbered with small tags and the pairs with similar numbers spliced together.

Defective Terminal Cable:—Sometimes moisture will be absorbed all the way through the cable at a terminal, crosses may develop in rubber cable on account of the rubber insulation being injured by too much heat, or the cable become damaged in some way requiring it to be replaced. In any of these cases a new terminal should be installed in place of the old one. The old terminal should be removed from the pole without disturbing the drop wires and the new terminal placed in the position occupied by the old one. After making the necessary tests, the new tap cable is spliced to the main cable, and the drop wires transferred to the new terminal, the old terminal and cable cut off and the splice closed. If the old terminal is of a type in which the terminal is independent of the tap cable and no trouble has developed in it, it may be sent to the storeroom and used *again.*

***Defective Lateral* Cable:**—Trouble will frequently develop *in a lateral* cable from crossed and open pairs. If *ere are no defects in* the sheath and the lateral has a

least 10 per cent. of spare pairs besides the ones in trouble, it will not pay to pull out the lateral but the splice where the lateral joins the main cable should be opened and all bad pairs cut dead in the lateral. This will clear the main cable pairs of trouble and the pairs can be used at other terminals or at the end of the cable. When this is done the terminal should be made to number straight, that is the bad pairs in the lateral should be transferred so to be the last pairs in the terminal. Thus if the lateral cable takes pairs 1 to 100, and there are 10 pairs cut dead, the terminal would read from 1 to 90, instead of having the bad pairs appear in an irregular manner. A record of this change should be made on the cable trouble report and a note be made on the drawing for that cable, giving the correct number of pairs ending at the terminal.

If the lateral cable has a hole in it and is full of moisture, it should be replaced as soon as possible. If all the subscribers are out of service, or the lines are not important, the lateral may be cut off and pulled out and a new piece pulled in and spliced up. If the lines are not all out and it is important that they be kept working, a piece of okonite or rubber cable should be multipled from the manhole to the terminal. After this is done the defective piece of cable is cut off and pulled out and replaced with a new one, and the rubber cable removed.

Defective Section of Aerial Cable:—Should an aerial cable be badly burned and trouble be found in a number of different places, it will be economical to replace the cable rather than to try to repair it. The limits of the faulty cable should be determined, a new section strung alongside of the old cable, and cut over.

Defective Section of Underground Cable:—Should a section of underground cable be defective, it should be replaced as soon as possible. It often happens that only a few pairs are bad in a section and it is a question whether or not it *is economy* to replace it. As a general rule, if over 10 per *cent. of the* conductors are bad in a section, it will be economical to install a new cable. The new cable should

pulled into a spare duct near the bad cable, and cut into the working cable and the defective piece cut out.

Cable Maintenance Rules:—Splicers and testmen should as far as possible rigidly observe the following rules:

1. Never leave lines out of service for more than one day.
2. Never open cable unless sure of trouble location.
3. Never split cable pairs.
4. Keep everything as dry as possible. Keep paper sleeves and bandages in a dry tin box.
5. Never leave a cable open any longer than is absolutely necessary and always provide protection from sudden showers when working on potheads or similar terminals.
6. Limit the use of split sleeves as much as possible, and never split a sleeve that can be slipped from the splice.
7. Never bandage a splice tight enough to crush the paper sleeves.
8. Before wrapping a splice boil it out twice and once afterwards, but avoid filling splices with paraffin.
9. Never use melted paraffin or cable compound without immersing a piece of rubber insulated wire in it for one minute, letting the paraffin or compound cool if hot enough to injure the rubber insulation.
10. Never leave a splice with any trouble in it.

CHAPTER VIII.

CABLE COSTS.

The cost of cable work varies greatly in differen tions of the country. The figures given in this chapt representative costs of work done under average cond and in a manner conforming to standard practice. ' fore, with proper allowance for any unusual local cond the matter given may be used in calculations with slight possible error.

First Cost of Cable:—The first cost of cables de upon the ruling prices of the raw materials entering the construction of the cable, and various other cond such as the proximity of the cable factory to the point the cable is to be used, rigidity of cable specification inspection, etc. The following tables give the averag of cables per foot made in accordance with the specific in Chapter I, and with the prices of raw materials as fo

Copper	$ .15	per pound
Lead	.045	per pound
Tin	.400	per pound

TABLE XV.

PRICES PER LINEAL FOOT, DRY CORE CABL

Number of pairs	22 ga.	19 ga. H. C.	19 ga. L. C.	16 ga.
10	$ .052	$ .072	$ .083	$ .109
15	.063	.089	.099	.138
25	.083	.114	.132	.195
50	.126	.197	.216	.299
75	.163	.264	.291	.431
100	.212	.384	.408	.563
150	.292	.509	.547	——
200	.408	.616	——	——
300	.547	.83	——	——
400	.682	——	——	——
600	.975	——	——	

TABLE XVI.

PRICES PER LINEAL FOOT, MISCELLANEOUS CABLES.

Kind.	Price per foot.
Rubber cable, 10 pair, 22 gauge	$0.168
Rubber cable, 15 pair, 22 gauge	.253
Rubber cable, 25 pair, 22 gauge	.313
Wool cable, 100 pair, 22 gauge	.44
Wool cable, 200 pair, 22 gauge	.72
Okonite cable, 25 pair, 19 gauge	.195
Okonite cable, 50 pair, 19 gauge	.44

Cost of Cable Work:—For use in the preparation of estimates and comparison of different plans or types of construction, it is necessary to add the labor cost of construction to the cost of materials. The figures used in arriving at the labor cost should be average unit labor cost figures, that is, each item should cover an individual operation, as placing messenger clamps, cable clips, etc., and should hold for the entire plant construction.

Unit Labor Costs:—To obtain these unit labor costs, a cost system should be established on all construction work, from which the cost of individual operations and their relation to the total cost can be determined. Methods of cost keeping with forms are given in "Telephone Construction—Methods and Cost," by Clarence Mayer.

Unit labor figures will vary greatly in different parts of the country, being dependent upon the wages for labor, character of the construction, character of the territory, etc.

The unit labor costs on cable work given in Table XVIII have been compiled from the records of work done by various companies in different cities and towns of the *middle western states*. The average wages paid on cable *work were as follows:*

TABLE XVII.

AVERAGE WAGES PAID ON CABLE WORK.

Foreman	Strand and cable work per 9 hrs.	$3.00
Linemen	Strand and cable work per 9 hrs.	2.50
Groundmen	Strand and cable work per 9 hrs.	1.75
Teams	Strand and cable work per 9 hrs.	3.50
Cable Splicer, 8 hrs		3.00
Cable Helper, 8 hrs		2.50

TABLE XVIII.

UNIT LABOR COSTS, CABLE WORK.

Boring holes for messenger clamp bolts	$ .04	each
Placing messenger clamp bolts	.04	each
Placing messenger clamps	.05	each
Placing guy clamps	.04	each
Placing cable crossarms	.15	each
Placing 10,000 lb. messenger wire	.005	per ft.
Placing 16,000 lb. messenger wire	.005	per ft.
Placing aerial cable, 25 pr. or smaller	.010	per ft.
Placing aerial cable, 50 pr	.011	per ft.
Placing aerial cable, 100 pr	.012	per ft.
Placing aerial cable, 150 pr	.013	per ft.
Placing aerial cable, 200 pr	.014	per ft.
Placing aerial cable, 300 pr	.015	per ft.
Placing aerial cable, 400 pr	.014	per ft.
Placing Marlin cable clips	.005	each
Placing aerial rings	.005	each
Placing 25 pr. cable box	.50	each
Placing 50 pr. cable box	.60	each
Placing 100 pr. cable box	.75	each
Placing 150 pr. cable box	1.00	each
Placing 200 pr. cable box	1.50	each
Placing 5 pair terminal	.30	each
Placing 10 pair terminal	.35	each
Placing 15 pair terminal	.40	each

Placing 25 pair terminal	.50	each
Placing pole seats	.75	each
Placing balconies	1.00	each
Soldering wires on terminals	.01	each
Insulating cable with rubber hose	3.00	each
Placing guy plates	.01	each
Placing guy hooks	.04	each
Placing guys	1.00	each
Anchor Shields placed	.25	each
Placing grounds	1.50	each
Placing bonds "Adams Bonding Lug"	.50	each
Placing underground cable, 25 pr	.01	per ft.
Placing underground cable, 50 pr	.012	per ft.
Placing underground cable, 100 pr	.015	per ft.
Placing underground cable, 150 pr	.018	per ft.
Placing underground cable, 200 pr	.020	per ft.
Placing underground cable, 300 pr	.021	per ft.
Placing underground cable, 400 pr	.022	per ft.
Placing underground cable, 600 pr	.03	per ft.
Testing 10 pr. cable	.30	each
Testing 15 pr. cable	.42	each
Testing 25 pr. cable	.52	each
Testing 50 pr. cable	.78	each
Testing 100 pr. cable	1.18	each
Testing 150 pr. cable	1.52	each
Testing 200 pr. cable	1.84	each
Testing 300 pr. cable	2.46	each
Testing 400 pr. cable	3.06	each
Testing 600 pr. cable	4.60	each
Splicing 2—25 pr. cables	.90	each
Splicing 2—50 pr. cables	1.23	each
Splicing 2—100 pr. cables	1.75	each
Splicing 2—150 pr. cables	2.52	each
Splicing 2—200 pr. cables	3.18	each
Splicing 2—300 pr. cables	4.50	each
Splicing 2—400 pr. cables	5.70	each
Splicing 2—600 pr. cables	6.36	each
Splicing 10 pr. tap from 25 pr. cable	1.75	each
Splicing 10 pr. tap from 50 pr. cable	2.01	each

Splicing 10 pr. tap from 100 pr. cable	2.48	each
Splicing 10 pr. tap from 150 pr. cable	2.63	each
Splicing 10 pr. tap from 200 pr. cable	2.78	each
Splicing 10 pr. tap from 300 pr. cable	3.12	each
Splicing 10 pr. tap from 400 pr. cable	3.41	each
Splicing 15 pr. tap from 25 pr. cable	1.85	each
Splicing 15 pr. tap from 50 pr. cable	2.08	each
Splicing 15 pr. tap from 100 pr. cable	2.57	each
Splicing 15 pr. tap from 150 pr. cable	2.70	each
Splicing 15 pr. tap from 200 pr. cable	2.83	each
Splicing 15 pr. tap from 300 pr. cable	3.16	each
Splicing 15 pr. tap from 400 pr. cable	3.50	each
Splicing 25 pr. tap from 25 pr. cable	3.12	each
Splicing 25 pr. tap from 50 pr. cable	3.33	each
Splicing 25 pr. tap from 100 pr. cable	3.50	each
Splicing 25 pr. tap from 150 pr. cable	3.93	each
Splicing 25 pr. tap from 200 pr. cable	4.12	each
Splicing 25 pr. tap from 300 pr. cable	4.40	each
Splicing 25 pr. tap from 400 pr. cable	4.76	each
Splicing 50 pr. tap from 50 pr. cable	3.23	each
Splicing 50 pr. tap from 100 pr. cable	3.77	each
Splicing 50 pr. tap from 150 pr. cable	4.28	each
Splicing 50 pr. tap from 200 pr. cable	4.81	each
Splicing 50 pr. tap from 300 pr. cable	5.71	each
Splicing 50 pr. tap from 400 pr. cable	6.55	each
Splicing 100 pr. tap from 100 pr. cable	4.81	each
Splicing 100 pr. tap from 150 pr. cable	5.62	each
Splicing 100 pr. tap from 200 pr. cable	6.43	each
Splicing 100 pr. tap from 300 pr. cable	7.52	each
Splicing 100 pr. tap from 400 pr. cable	8.04	each
Splicing 150 pr. tap from 150 pr. cable	5.81	each
Splicing 150 pr. tap from 200 pr. cable	6.56	each
Splicing 150 pr. tap from 300 pr. cable	7.58	each
Splicing 150 pr. tap from 400 pr. cable	8.63	each
Splicing 200 pr. tap from 200 pr. cable	7.13	each
Splicing 200 pr. tap from 300 pr. cable	8.27	each
Splicing 200 pr. tap from 400 pr. cable	9.34	each
Splicing 300 pr. tap from 300 pr. cable	10.00	each
Splicing 300 pr. tap from 400 pr. cable	10.65	each

Splicing 400 pr. tap from 400 pr. cable	11.28	each
Making 25 pr. pothead	2.85	each
Making 50 pr. pothead	3.95	each
Making 100 pr. pothead	6.50	each
Making 150 pr. pothead	7.40	each
Making 200 pr. pothead	9.00	each
Making 100 pr. wool butt	6.00	each
Making 200 pr. wool butt	8.50	each

The above figures include the cost of supervision, travel, and expense, the approximate percentage for these items being as follows:

Engineering and Supervision	10 per cent.
Travel	5 per cent.
General Expense	5 per cent.

The following example shows the method of using these unit costs in making an estimate:

Labor cost of 1,000 feet of 50 pr. 22 ga. cable in place including terminals.

1200-ft. 10,000 lb. messenger wire strung @ $.005	$ 6.00
10-holes bored @ $.04	.40
10-messenger clamp bolts placed @ $.04	.40
10-messenger clamps placed @ $.05	.50
1000-ft. 50 pr. 22 ga. cable placed @ $.011	11.00
600-marlin clips placed @ $.005	3.00
1-50 pr. cable tested	.78
1-50 pr. straight splice made	1.25
3-15 pr. terminals placed @ $.40	1.20
1-10 pr. terminals placed @ $.35	.35
3-15 pr. taps from 50 pr. cable @ $2.08	6.24
3-15 pr. taps tested @ $.42	1.26
1-10 pr. taps from 50 pr. cable	2.01
1-10 pr. taps tested	.30
1-bond placed	.50
Portion of ground cost 1/5 on basis of 1 ground to *5,000 feet of cable*	.30
Total	$ 35.49

Annual Charges:—As outlined in Chapter II, the result of adopting a certain type of construction must be figured in dollars and cents not only for the present time, but for future periods of five, ten, or twenty years hence.

For general estimate work where no particular data as to local conditions affecting the life of the material or other factors affecting the annual charge is known, the figures given in Table XIX may be used. All figures are percentages of the first cost of the material in place, although where maintenance charges are likely to be an important factor in the final results, such charges should preferably not be expressed as a percentage of the cost of the installation. For instance, the most expensive installation may give the least maintenance cost, whereas on a percentage basis the reverse would be shown. However, as the maintenance figure becomes a relatively small portion of the whole when the total annual charges are being considered, the maintenance cost is for convenience of computation expressed like the other items, as a percentage of first cost. Maintenance includes only items of current repair and does not cover operating expenses or reconstruction.

"Depreciation" covers reconstruction.

Taxes are given at a uniform rate of 1 per cent. with ½ per cent. added in the case of exchange poles, which is to care for local municipal taxes.

Interest is taken at a uniform rate of 6 per cent. for all classes of construction.

TABLE XIX.

ANNUAL CHARGES ON TELEPHONE CONSTRUCTION.

	Interest.	Taxes.	Depre-ciation.	Mainte-nance.	Total.
Underground conduit	6	1	2	½	9½
Toll line poles	6	1	8½	4	19½
Toll line crossarms	6	1	11	4	22
Exchange poles	6	1½	12	5	24½
Exchange crossarms	6	1	12	5	24
Messenger wire	6	1	6	3	16
Terminals and cable boxes	6	1	8	3	18
Aerial cable	6	1	6	3	16
Underground cable	6	1	3½	1	11½
Bare copper, toll	6	1	2	5	14
Bare copper, exchange	6	1	5	5	17
No. 14 twisted pair (drops)	6	1	9	3	19
Iron wire, toll	6	1	8½	5	20½
Iron wire, exchange	6	1	14	5	26

APPENDIX.

TABLE XX.

LEAD COVERED DRY CORE CABLE.

Data for No. 22 B. & S. Gauge.

No. of pairs.	Outside diameter inches.	Thickness of sheath inches.	Weight per ft. pounds.	Weight lead per ft. pounds.	Weig of copp per f poun
10	.5	1/12	.60	.552	.04
15	.7	1/12	.8	.727	.07
25	.8	1/12	.95	.83	.12
50	1.0	1/12	1.4	1.16	.24
100	1.4	3/32	2.2	1.69	.51
150	1.6	3/32	2.8	2.1	.70
200	1.8	1/8	4.15	3.21	.94
300	2.1	1/8	5.2	3.75	1.45
400	2.4	1/8	6.25	4.22	2.03
600	....	1/8	8.1	4.95	3.05

TABLE XXI.

Data for No. 19 B. & S. Gauge, .080 Mutual Capacity.

No. of pairs.	Outside diameter inches.	Thickness of sheath inches.	Weight per ft. pounds.	Weight lead per ft. pounds.	Weigl of copp per f pounc
10	.7	1/12	.9	.818	.08
15	.8	1/12	1.0	.875	.12
25	.9	1/12	1.3	1.04	.26
50	1.2	3/32	2.1	1.57	.53
100	1.7	1/8	4.0	3.12	.88
150	2.0	1/8	4.9	3.55	1.35
200	2.2	1/8	5.8	3.91	1.84
300	2.5	1/8	7.A	4.88	2.9

TABLE XXII.

Data for No. 19 B. & S. Gauge, .054 Mutual Capacity.

No. of pairs.	Outside diameter inches.	Thickness of sheath inches.	Weight per ft. pounds.	Weight lead per ft. pounds.	Weight of copper per ft. pounds.
10	.8	1/12	1.1	1.018	.082
15	.9	1/12	1.2	1.075	.125
25	1.1	1/12	1.5	1.24	.26
50	1.4	3/32	2.4	1.87	.53
100	2.0	⅛	4.4	3.52	.88
150	2.3	⅛	5.6	4.25	1.35

TABLE XXIII.

Data for Wool Insulated Cable, No. 22 B. & S. Gauge.

Number of pairs.	Outside diameter inches.	Weight per foot pounds.
100	1.3	2.3
200	1.75	3.45
400	2.50	6.00

TABLE XXIV.

Data for Rubber Cable, No. 22 B. & S. Gauge.

Number of pairs.	Outside diameter inches.	Weight per foot pounds.
10	1.0	1.5
15	1.2	1.8
25	1.5	2.5

TABLE XXV.

Data for Okonite Cable, No. 19 B. & S. Gauge.

Number of *pairs.*	Outside diameter inches.	Weight per foot pounds.
25	1.1	.64
50	1.5	1.24
100	2.3	2.25

TABLE XXVI.

Messenger Wire Data.

Size.	Wire diameter in inches.	Breaking weight in lbs. minimum.	Diameter of strand in inches.	Weight per ft. pounds.
10,000 lb.	.120	11,500	3/8	.....
16,000 lb.	.144	18,000	7/16	.405

TABLE XXVII.

Splicer's Outfit.

Tools:

1 Plumber's gasoline furnace (filled with gasoline).
1 6-inch solder pot.
1 One-gallon enamel coffee pot, for compound.
1 Stripping knife.
1 One-gallon enamel coffee pot, for paraffin.
1 Lead pipe dresser.
1 Small mirror.
1 Grease pot with stickers.
1 Lead pipe scraper.
2 Four-pound soldering irons.
1 3-inch ladle for wiping metal.
1 Pair of electrician's scissors.
1 Sheet iron pan, 3 inches deep by 26 inches long, by 16 inches wide.
4 Pieces of flexible waterproof oilcloth, each 1 yard square.
1 Tarpaulin, about 7 feet square.
1 Lineman's test set.
1 Tool bag.
1 Tool chest, with hinged lid, padlock and handles.

Material:

1 Gallon jug filled with gasoline.
5 Cakes of wiping metal (40% tin, 60% lead by weight).
500 Tags.
1 Roll of okonite tape.
5 Rolls of friction tape.

1 Can of compound.
1 Tin box full of paper sleeves one-eighth (1/8) inch inside diameter by two and one-half (2½) inches long, boiled in paraffin (for No. 22 B. & S. gauge wire).
1 Tin box full of paper sleeves three-sixteenths (3/16) inch inside diameter by three (3) inches long, boiled in paraffin for No. 19 B. & S. gauge wire.
4 Sticks half and half solder.
1 Sheet of manilla paper. .006" thick, 36" square.
4 Rolls of muslin, 3" wide by 10 ft. long.
1 Cake paraffin.
3 Lead sleeves, size depending on the size of the cable upon which work is to be done.

TABLE XXVIII.

Weights of Lead Sleeves.

1 in. by 40 in.	4 lb. 8 oz.
1½ in. by 40 in.	10 lb. 8 oz.
2 in. by 40 in.	13 lb. 6 oz.
2½ in. by 40 in.	16 lb. 6 oz.
3 in. by. 40 in.	20 lb. 0 oz.
3½ in. by 40 in.	22 lb. 8 oz.
4 in. by 40 in.	26 lb. 8 oz.
4½ in. by 40 in.	

TABLE XXIX.

Material Required for Splicing. No. 22 B. & S. Gauge Cable.

Number of Pairs.	25	50	75	100	150	200	300	400
Wiping metal, lbs...	1½	2	3	3	4	5	7	8
Paraffin, lbs.	½	¾	1	1	1½	1½	2	2
Gasoline, gals.	¼	½	¾	¾	1	1	1	1
Size of sleeves, ins. straight splice	1½	2	2½	2½	2½	3	3½	3½
Size of sleeves, ins. "Y" splices	1½	2½	3	3½	4	4	4½	4½

TABLE XXX.

Material Required for Splicing. No. 19 B. & S. Gauge Cable.

Number of Pairs.	25	50	75	100	150	200	300
Wiping metal, lbs.....	2	3	4	4½	6	7	8
Paraffin, lbs.	½	¾	1	1	1½	1½	2
Gasoline, gals.	¼	½	¾	¾	1	1	1
Size of sleeve, ins. straight splice	1½	2	2½	3	3	3½	4½
Size of sleeve, ins. "Y" splice	1½	2½	3	3½	4	4½	4½

TABLE XXXI.

Change of Insulation Resistance and Electrostatic Capacity of No. 19 B. & S. Gauge Lead Covered Dry Core Cable With Change of Temperature.

Temperature Degrees Fahrenheit	Insulation Megohms per mile	Capacity Microfarads per mile
60	7000	.0800
65	4200	.0807
70	2850	.0814
75	2100	.0821
80	1500	.0828
85	1020	.0836
90	910	.0845
95	740	.0859
100	600	.0875
105	470	.0895
110	360	.0918
115	260	.0944
120	180	.0972
125	130	.1003

Table XXXI from Handbook of Standard Underground Cable Company, prepared by H. W. Fisher.

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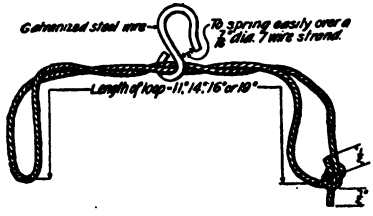

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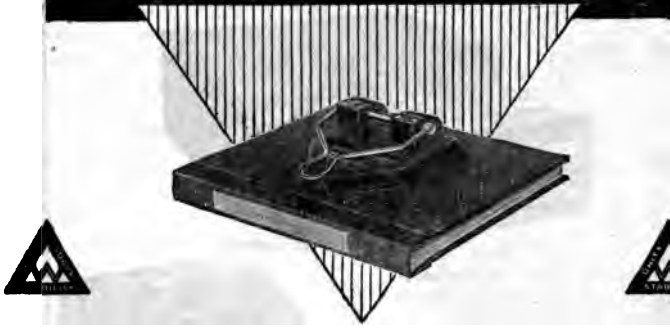

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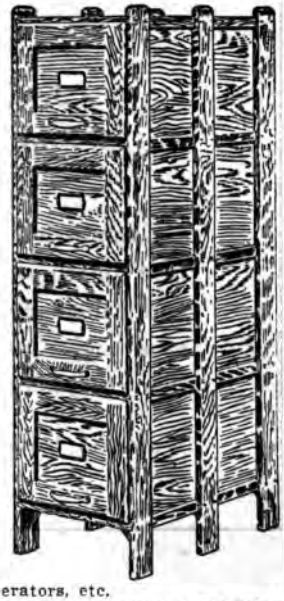

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